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A SUMMARY OF THE ANATOMY *of* THE INFANT AND CHILD

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CHAPTER III

A SUMMARY OF THE ANATOMY OF THE INFANT AND CHILD

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INTRODUCTORY NOTE

The study of the anatomy of childhood is not a new one. The first work on this subject was written over 400 years ago and upwards of 300 theses, separate articles, and books were published prior to the nineteenth century. In recent years, the use of modern microscopical technique and the Roentgen-ray, and the introduction of the newer methods of statistical inquiry have greatly widened the field and enriched the literature. In 1913 alone there appeared over 300 articles dealing with the anatomy and physical development of the child; and a complete bibliography of the subject to date would probably contain between 5,000 and 6,000 titles.

The existence of this mass of literature should not lead one to the conclusion that the subject is now a closed one. On the contrary, probably no other branch of human morphology is so incompletely known. Most of the work has been done by students in widely separated fields—in human anatomy proper, pediatrics, anthropology, obstetrics, and legal medicine; and as there has been no central organ to correlate these investigations, we find frequent duplications of studies on the one hand and entire neglect of many phases of the subject on the other. These conditions make the production of even a moderately complete outline of the subject particularly difficult.

In order to cover the field as adequately as possible in a limited space the following general plan has been pursued.

The subject is presented from the systematic standpoint, but an effort has been made to cover the topography of the more important regions by means of a considerable number of illustrations which are cross-indexed under the various special headings.

Pre-natal development is considered only when necessary to make clear post-natal changes.

No details are given regarding structures which are practically the same in childhood and maturity since this information is easily available in better form elsewhere. Certain special subjects, such as the brain, the organs of special sense, the teeth, and the nasal sinuses, have necessarily received brief treatment; but references to more complete presentations are included in the text.

As many of the changes of the body during the period of post-natal development are best expressed numerically I have made frequent use of tables. These are generally based upon data collected from the literature, and on personal observations.

Finally, I have tried to point out some of the phases of the subject where our information is inadequate or our data conflicting.

An outline of this sort must be a mixture of the common knowledge of the subject, of personal observations, and of the conclusions of many other investigators. The last I have tried to acknowledge, in as far as space permitted, in the bibliography, but in common with all students of this field, I am particularly indebted to the works of Ballantyne, Symington and Gundobin.

THE SKELETON

General Remarks

As is well known the process of ossification begins in a number of discrete foci which are known as centers of ossification. These centers may appear either in membrane or in cartilage; in man by far the larger are formed in cartilage. The formation of ossification centers extends over a considerable period in the life of the individual. The first to appear (that of the shaft of the clavicle) is found in embryos of the sixth week while some associated with the vertebral column are not formed until near the end of the second decade of post-natal life. In all, something over 800 ossification centers are formed in the human body and of these slightly more than half appear after birth.

Almost all bones of the adult are formed from two or more centers of ossification; the relation of the total number of bones in the mature skeleton to the total number of centers being approximately as one is to four. The ossification centers of all bones of the body, with the exception of those of the carpus, tarsus, skull and sternum, may be divided into two general classes, the primary and the secondary. The primary centers, which form the greater part of the bone, almost always appear before birth. Such centers, when located in long bones are known as diaphyses. The secondary centers or epiphyses are, with one or two exceptions, formed during post-natal life. A further consideration of the nature of diaphyses and epiphyses will be found in the section dealing with development of the bones of the extremities.

As the formation of new centers and the fusion of older ones proceed at unequal rates during the first two decades, the number of separate bone-masses in the body varies from year to year during this period. Table 1 is a numerical summary showing some of these changes. As will be seen from this table the number of bones in the average full-term newborn child is 270. This number is somewhat reduced in the first two or three years of life through the fusion of primary centers which were present before birth. From this time until puberty, however, the number increases steadily through the formation of epiphyses and the ossification of the tarsus and carpus. In the fourteenth year there are about 350 separate bony masses in the body.

Table 1.—Approximate Number of Ossification Centers and Separate Bones in the Human Skeleton at Different Ages

(Sesamoid bones omitted with the exception of the patellæ)

	Skull including auditory ossicles and hyoid bone	Vertebral column	Ribs and sternum	Upper extremity	Lower extremity	Total (paired bones counted as two)
Total number of centers formed	Circa 120	Circa 295	Circa 101	Circa 140	Circa 140	Circa 806
Number of centers appearing after birth	9	Circa 197	73	82	88	Circa 443
Number of separate bones at birth	45	93	34	48	50	270
Number of separate bones in fourteenth year	Circa 33	Circa 33	Circa 29	Circa 124	Circa 136	Circa 356
Number of separate bones at maturity	29	26	25	64	62	206

After puberty the number of bones is again decreased rapidly until nearly the middle of the third decade and then much more slowly. Often it is not until late middle life that the number of bones is reduced to the quota of 206 generally accepted as the normal number in the human body excluding the smaller sesamoids.

There are great differences in the rates of bone formation in the different parts of the skeleton. In the skull, where the bones have no epiphyses, there is a steady reduction in the number of bones from birth to maturity. The spine shows a reduction in the number of bony elements during childhood due to the fusion of the primary centers of the vertebræ; but from puberty to 20 years there is a marked increase through the formation of epiphyses. Following the twentieth year the number again decreases, rapidly at first, through the fusion of epiphyses and primary centers and later more slowly as the segments of the sacrum and coccyx join one another. The number of separate bones in the thorax remains constant during childhood, is greatly increased by the formation of the epiphyses of the ribs after puberty, and is reduced after the twentieth year by the union of these epiphyses with their shafts and by the coalescence of the segments of the sternum. The number of separate bones of the skeleton of the extremities increases threefold between birth and puberty through the ossification of the tarsus and carpus and the formation of the epiphyses. After puberty, as the epiphyses unite with their respective shafts, the number of bones is reduced to practically that of the newborn appendicular skeleton plus the number of tarsal and carpal bones.

Together, the bony and cartilaginous skeleton form from 15 to 20 per cent. of the total body weight at birth. Its post-natal growth proceeds parri passu with that of the body as a whole and, so far as our rather meagre statistics show, the proportions between the skeleton and body-weight which exist at birth remain practically unchanged during childhood and maturity. The absolute post-natal increase in the weight of the skeleton, like that of the body as a whole, is roughly twenty-fold.

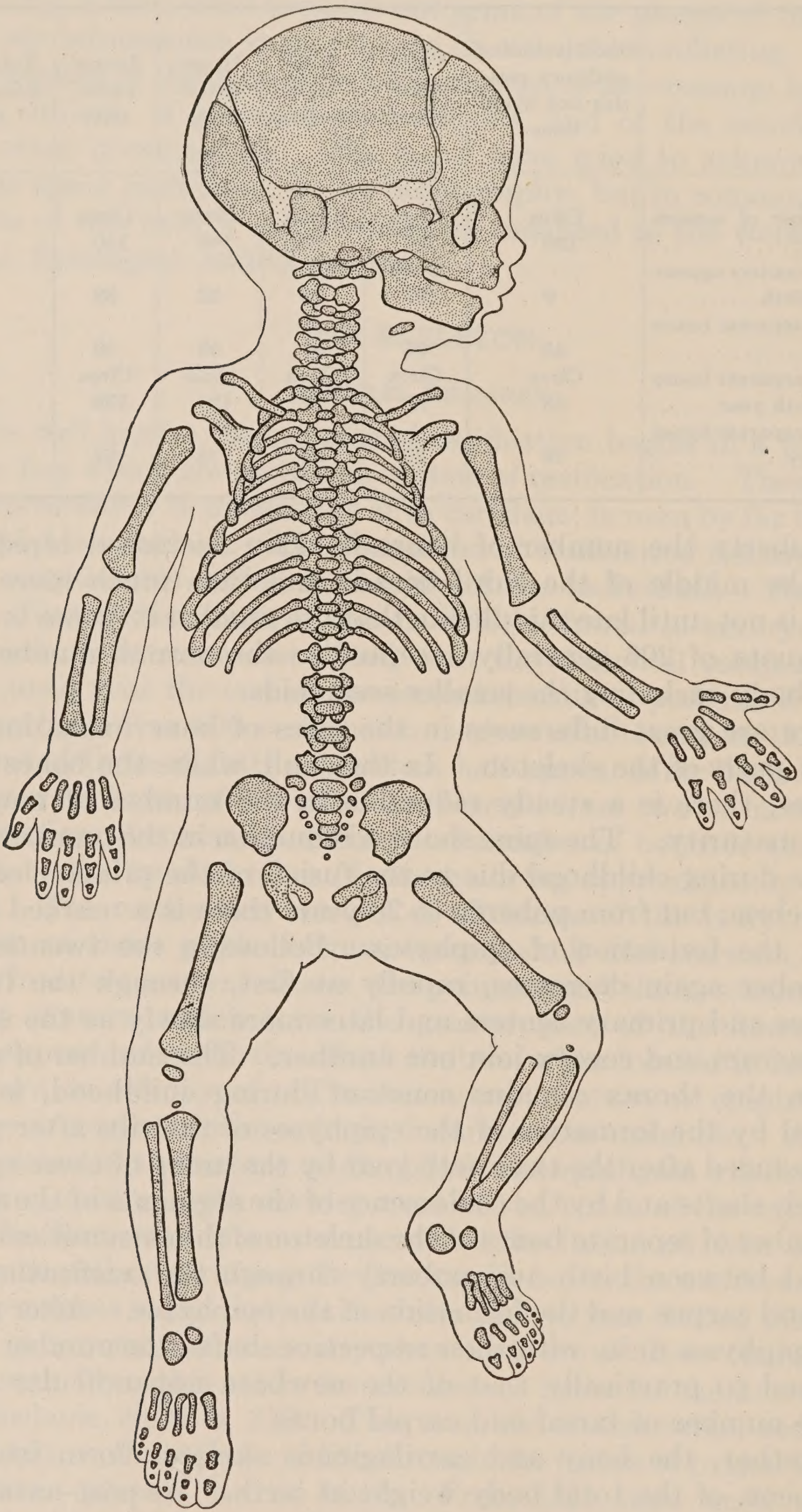

FIG. 84.—A semi-diagrammatic outline of the skeleton of the full-term new-born as seen with the roentgen-ray. The ossification centers of the sternum are omitted. (Slightly modified from Hess.[29])

FINER STRUCTURE OF THE BONES IN CHILDHOOD

As the histology of bone development is described in almost every modern anatomical text the present section is limited to a summary of the finer structure of fully formed osseous tissue in childhood.

The bones of the infant are much more spongy in structure than those of the adult. This sponginess or porosity has recently been studied quantitatively by Toppich [57] who found that nearly 60 per cent. of the bulk of the bony skeleton of the newborn was made up of material other than osseous tissue. With the exception of the vertebral column, all the divisions of the skeleton show a reduction in porosity during childhood. In the vertebral column the porosity increases from about 61 per cent. in the newborn to 75 per cent. in the mature skeleton.

The histologic picture presented by sections of the long bones of young infants is quite different from that seen in the adult. In the former the bone has a reticular rather than a lamellar arrangement and often no sharp distinction can be drawn between the spongy and compact portions. The Haversian canals are numerous and relatively large, and tend to run in circles concentric with the periphery of the bone rather than parallel to its long axis. There are many anastomotic canals which connect the Haversian canals with one another and with the internal and external surfaces of the bone. The number of lamellæ surrounding each Haversian canal, as well as the number of periosteal lamellæ, is less in the infant than in the adult. The fibers of Sharpey on the other hand are more numerous and larger in the infant. The bone corpuscles also are said to be larger in early life.

Bone growth takes place very rapidly in infancy and by the age of two years most of the peculiar characteristics of the long bones of sucklings are lost. According to Gundobin,[7] however, it is not until the age of 12 that the structure of the long bones becomes identical with that of the adult.

In infancy the flat bones of the skull differ considerably in their various parts. At the time of birth the inner and outer tables can be easily recognized in the region of the eminences, where they are separated by a narrow marrow cavity. As in later life the outer table is thicker than the inner. Along the growing margins of the bones, however, the structure is still reticular and remains so for some time after birth. Haversian canals are present in the older parts of the calvarial bones at the time of birth.

The periosteum is from one-third to one-half as thick in the newborn as in the adult (Schulz).[55] During early childhood, at least, there is a definite inner osteogenic layer rich in osteoblasts and containing few connective tissue fibers. The osteoblasts are so numerous in the inner layer of the periosteum of the long bones at birth that they have almost an epithelial arrangement. By the end of the twentieth year the osteoblastic layer is greatly reduced or completely fused with the middle or fibro-elastic layer of the periosteum.

THE SKULL

The skull at birth (Figs. 84, 85, 86, 87, 180).—The most striking characteristic of the skull of the newborn child is the preponderance of the neural or calvarial portion over the facial. The relation between the two at birth is as 8:1 as compared to the ratio of 2.5:1 in the adult female and 2:1 in the adult male. The calvarium is also much larger in proportion to the base of the cranium than in adult life. The bones of the cranial vault are quite thin and are separated by narrow strips of tough membrane. At the angles of the parietal bones these membranous strips become continuous with the fontanelles. These structures are described in a following section. Each parietal bone and each half of the divided frontal bone presents, near its center, a rounded eminence. These elevations mark the approximate position of former ossification centers. When viewed from above, the frontal and parietal eminences, together with the less noticeable projection of the occipital bone, give the skull an elongated pentagonal outline.

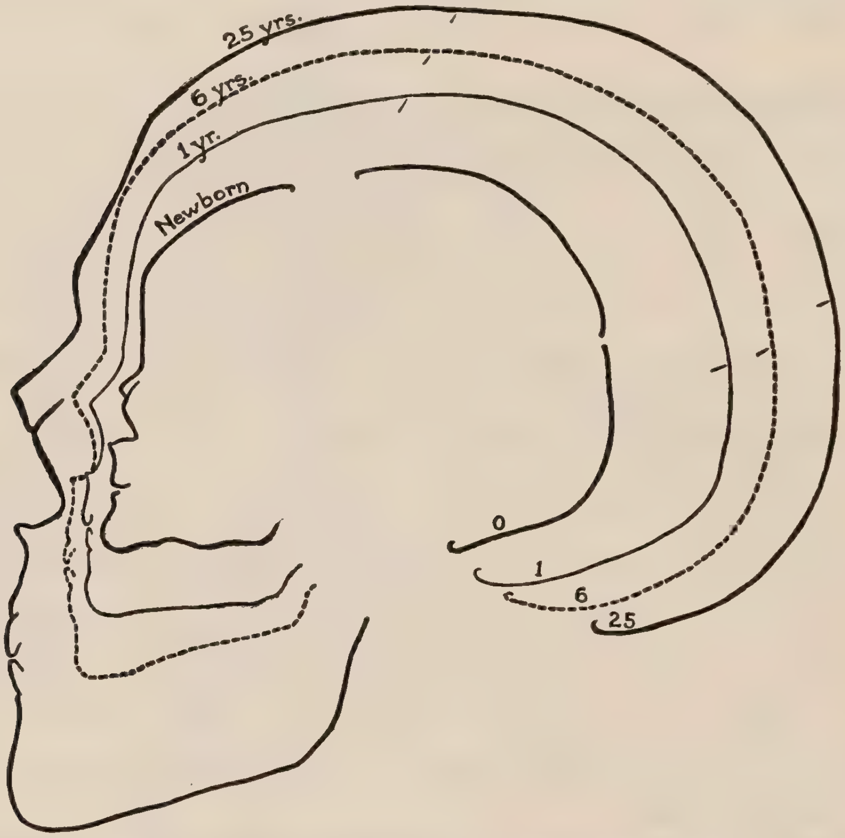

FIG. 85.—A series of median longitudinal sections of skulls illustrating the relative growth of the cranium and facial skeleton from birth to maturity. All specimens one-half natural size. (Slightly modified from Welckler, Arch. f. Anthropol., I, 1866.)

The width of the face is relatively less in proportion to the cranium than in the adult but in comparison to its height it is twice as broad as in maturity. The upper portion of the face is much more completely developed than the lower. The orbits are large and rounded with sharp margins. The nasal aperture is large, broad, and rounded and the inferior nasal spine is well marked. The upper and lower jaws are broad and very low. They present a series of rounded elevations which contain the dental sacs of the milk-teeth.

The base of the skull is small compared to the vault which extends beyond it laterally and posteriorly. Its surface is without marked elevations. The hard palate is short and broad and the choanæ are almost circular. Both the lateral and medial lamina of the pterygoid process are plate-like and extend forward and outward at an acute angle with the base of the sphenoid bone. There are no true bony auditory meati at this time but the ear drums with their surrounding tympanic rings form prominent features of the base of the skull. The foramen magnum is relatively larger in the newborn than in later life and is placed more anteriorly in the base of the skull. In the infant the anterior margin of the foramen magnum lies at a distinctly higher level than the posterior while in the adult the plane of the foramen is almost horizontal. The condyles are not raised above the general surface of the occipital bone and are quite flat both anteroposteriorly and from side to side. As a result, movement at the occipitoatalantoid joint is quite limited in infancy and most movements of the head are brought about through the mobility of the cervical intervertebral joints.

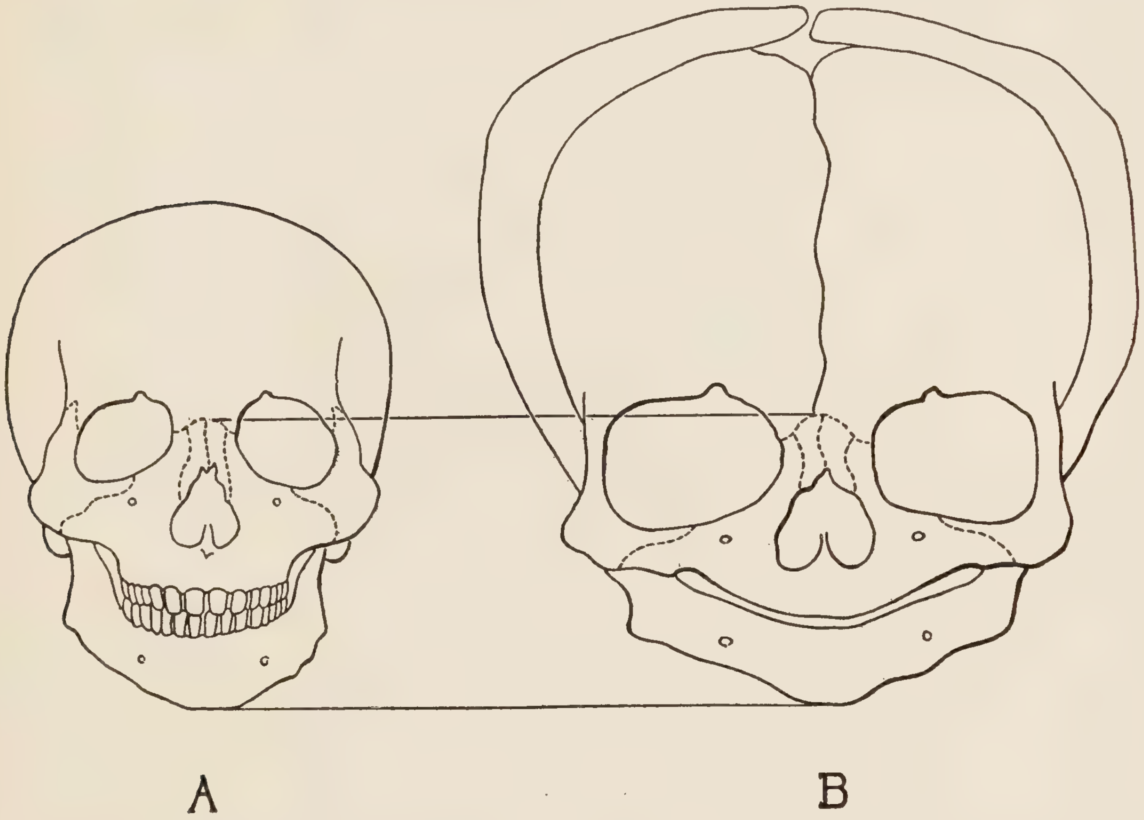

Fig. 86.—A diagram illustrating the post-natal changes in the proportionate height of the cranium and face. A, adult skull; B, skull of a newborn child. The two specimens are drawn so that the facial heights (from nasion to pogonion) are equal. (After Holl.[30])

The Post-natal Development of the Skull (Figs. 85, 86, 87, 181, 186).—The skull as a whole grows relatively less in post-natal life than the other divisions of the skeleton. Between birth and maturity the neural portion increases four or five times and the facial part about 12 times in volume. During the same period the cranial capacity increases about three and one-half times (from about 400 c.c. to 1300 to 1500 c.c.) and the horizontal circumference approximately 50 per cent. (circa 35 cm. to 50 to 55 cm.). Most of this growth takes place in the first two years of life. The development of the skull is intimately associated with the growth of the other structures of the head, particularly with that of the brain and eye-balls, the teeth, and certain of the larger muscles. These structures affect the growth of the skull at quite different periods; the brain and eye-balls mainly during the rapid growth of early infancy, the teeth mainly during the period of establishment of the permanent dentation and the muscles mainly in later childhood and after puberty.

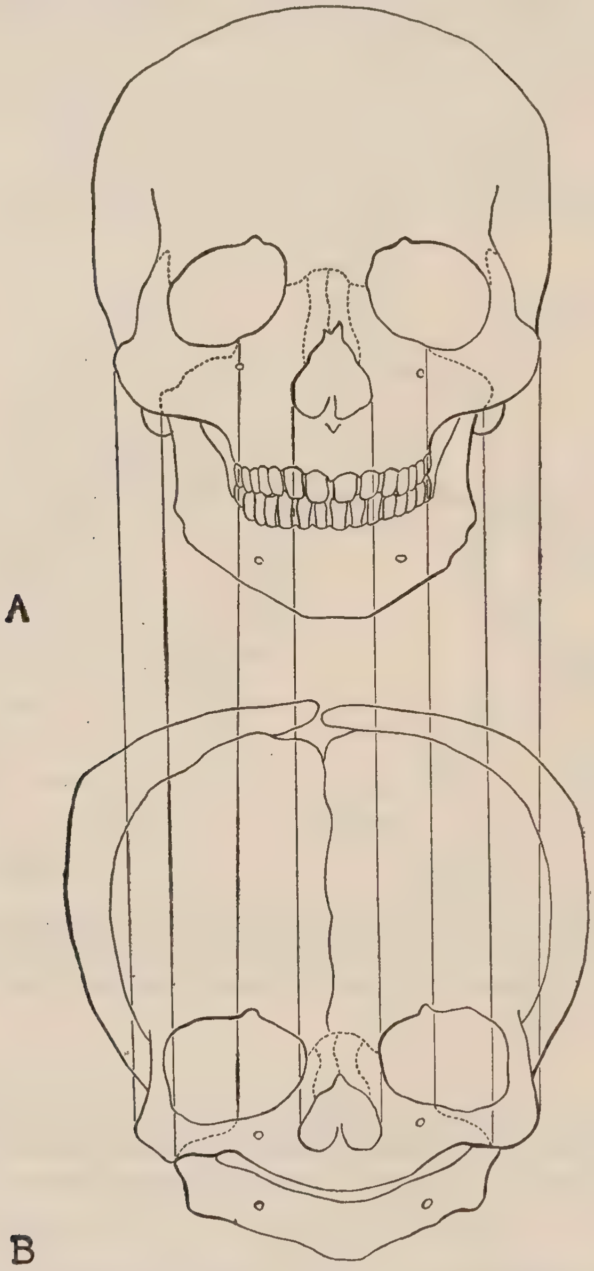

Fig. 87.—A diagram illustrating the post-natal changes in the breadth of the facial skeleton and the cranium. A, adult skull; B, skull of a newborn child. The two specimens are drawn so that the facial breadths (bimalar diameters) are equal. (After Holl.[30])

The methods of Roentgenography have not been applied successfully as yet to the study of post-natal skull development. All of our knowledge of the subject is based either upon measurements of the head in the living or on the examination of prepared skulls. The latter are often warped in drying and may be of uncertain history. Consequently any description of the process can be regarded merely as an outline subject to revision as more data are collected by modern methods. Following Merkel,[41] three general periods can be recognized in the post-natal development of the skull. The first period, in which the skull grows rapidly, is from birth to about seven years. The second, a period of slow growth, is from seven years to 10 or 12 years. The third, in which the rate of growth again increases somewhat, extends from 10 or 12 years to about 19 in the female and a little later in the male. During early infancy all parts of the skull grow rapidly. The cranial capacity increases from about 400 c.c. in the newborn to 700 c.c. at six months, 900 c.c. at 12 months, and about 950 c.c. at 18 months. The horizontal circumference increases in the same period from about 35 cm. at birth to about 47 cm. at 18 months. The growth of the occipital portion of the vault is more rapid than that of the frontal and parietal portions. During this period the facial skeleton grows even more than the cranium so that the relation between the two of 1:8 at birth is reduced to 1:6 in the course of the second year. This growth of the face is due in part to the increase in the size of the orbits, which accomplish over half of their post-natal growth in the first two years of life, and in part to the expansion of the maxillæ. After 18 or 20 months the growth of the skull, although continued, is less rapid. The cranium continues to expand, the vault growing more rapidly than the base up to seven years. The facial skeleton continues to grow more rapidly than the cranium and by five years the relation between the two is as 1:5. Most of the growth of the facial skeleton is in the lower part of the face and is due to the lateral expansion of the hard palate and the development of the maxillary sinus. By the end of the seventh year many parts of the skull, such as the body of the sphenoid bone, the cribriform plate of the ethmoid bone, and the petrous portion of the temporal bone have attained their final size; while other parts, such as the orbits, have almost reached adult dimensions. From 7 to 10 years the skull grows but little, aside from the lengthening of the face which accompanies the establishment of the permanent dentation. From 10 or 12 years to the end of the second decade growth again becomes more rapid. The cranium grows slightly in all directions through the increase in thickness of the bones forming it; and more strikingly anteriorly through the further development of the nasal skeleton and the growth of the upper and lower dental arches. The eminences of the cranium are lost, entirely or in part, and the various muscular ridges become prominent. As a rule these changes of the third period of skull development are less extensive in the female than in the male skull.

The Fontanelles (Figs. 84, 88, 89, 90).—The fontanelles are membranous plates which at birth and for a variable period thereafter bridge the gaps occurring between the angles or margins of certain bones of the cranium. In structure they consist of three layers of membrane; an outer which is continuous with the pericranium, an internal which is continuous with the endocranium, and a middle which is composed of a highly vascularized connective tissue which is later replaced by the ingrowth of bone.

Six fontanelles are normally present at birth. Two of these are single and median in position. These are the frontal or great fontanelle, which occupies a diamond shaped space between the two parietal bones, and the two (separated) halves of the frontal; and the occipital or lesser fontanelle which lies between the posterior median angles of the parietals and the upper angle of the occipital bone. The lateral fontanelles consist of two pairs. The anterior, stephanal, or sphenoid fontanelle is generally bounded by the squamous portion of the temporal bone, the greater wing of the sphenoid bone, the sphenoid angle of the parietal bone, and the lateral and posterior angle of the frontal bone. The posterior, lateral, or mastoid fontanelle lies between the mastoid angle of the parietal bone, the mastoid and squamosal

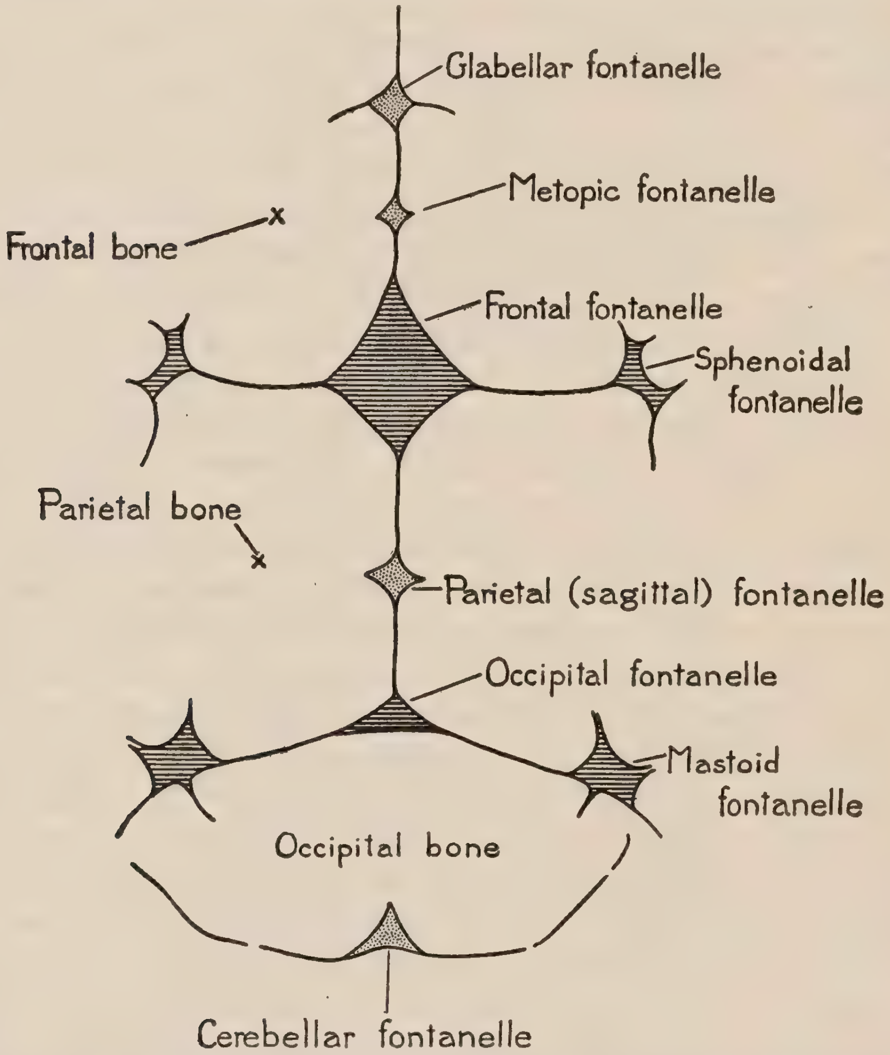

FIG. 88.—A diagram showing the form and position of the constant and principal accessory fontanelles at birth. The constant fontanelles are shaded in cross-lines; the accessory fontanelles are shaded in stipple.

portions of the temporal, and the supra-occipital portion of the occipital bone. The mastoid fontanelles are often shaped like an inverted L with the horizontal limb of the L extending forward over the superior margin of the temporal bone and the vertical one directed downward medially to come in contact with the basi-occipital portion of the occipital bone.

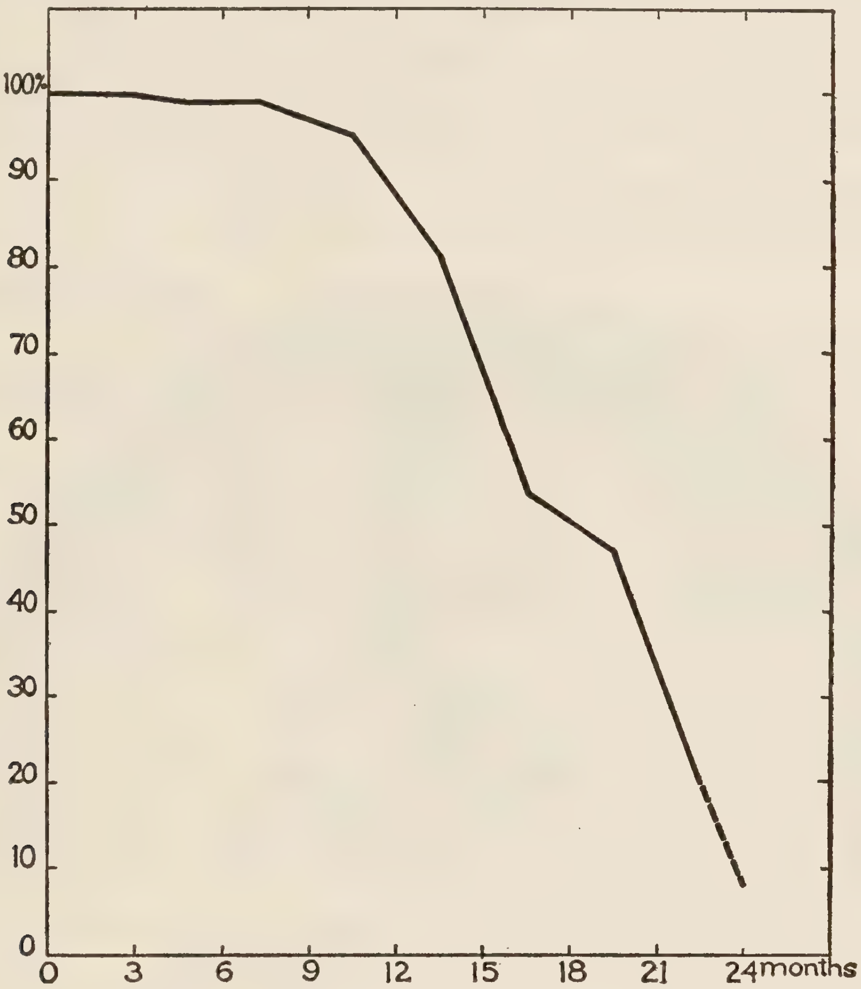

FIG. 89.—A curve showing the average percentage of open frontal fontanelles, as determined by palpation, in each trimester from birth to two years. (Based upon the data presented in table 2. Total number of cases, 945.)

Besides these constant fontanelles numerous accessory ones occur occasionally in various parts of the cranium. Frasseto[23] has listed nearly 20 of these structures but only a few are at all common or liable to be of practical importance. All of the more important accessory fontanelles are located along the sagittal suture. The glabellar fontanelle is a very unusual one located between the two halves of the frontal bone above and the two nasal bones below. When of any size it is commonly associated with other serious anomalies of the nasal skeleton. The metopic fontanelle is located just above the glabellar in the metopic suture which separates the two halves of the frontal bone and is found in about one skull in six of children under one year of age. As a rule it is an insignificant cleft but it may acquire some size when present in cases of hydrocephalus. It is sometimes confluent with the frontal fontanelle and is regarded by Schultz[54] as as anterior extension of this structure. The sagittal fontanelle lies between the medial margins of the two parietal bones in a line drawn between the two parietal eminences. It is diamond shaped or triangular in outline and is palpable in about 5 per cent. of all newborn children. The cerebellar fontanelle is a small gap in the upper margin of the foramen magnum caused by the failure of development of a small ossicle which generally forms a part of the occipital bone in this region. A cerebellar hernia may protrude through this space when it is of unusual size. Figure 88 is a diagram of the calvarium as seen from above and indicates the position of all the normal and the more common accessory fontanelles.

It is only within recent years that the post-natal involution of the fontanelles has been carefully studied. The older writers (Elsässer, Roger and Friedleben) were of the opinion that the greater fontanelle increased in size for several months after birth, an opinion still to be found in some of our texts today. This conclusion however was based upon studies of children of whom some were premature or rachitic. All modern studies show that, with the exception of prematures, the frontal fontanelle, beginning some weeks after birth, undergoes a regular course of involution. Some statistics of this process are shown in Table 2, and Fig. 89 is a graphic representation of a part of these data. The average diameter of the fontanelle in a full-term newborn, as determined by Elsässer's method* is approximately one inch (25 mm.) being a little greater in boys than in girls. The surface area is approximately 3.75 square cm. although it is difficult to determine it exactly at this time because of the continuity of the fontanicular space with the gaping coronal and sagittal sutures. The reduction of this area goes

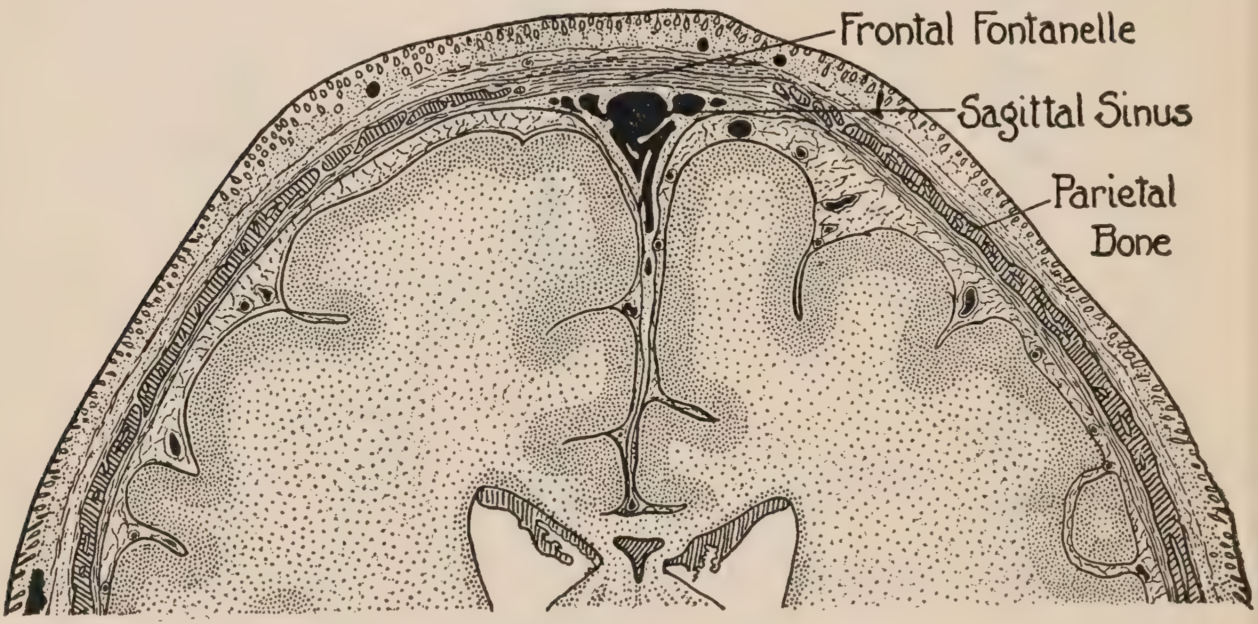

FIG. 90.—Frontal section of the frontal fontanelle, sagittal sinus and adjacent structures in a full-term newborn child.

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* Elsässer's diameter.—The average of the two oblique diameters taken from the middle of the fontanicular margin of one frontal bone to the middle of the fontanicular margin of the parietal bone of the opposite side.

on steadily in normal children although at widely varying rates in different individuals and apparently more rapidly in girls than in boys. As will be seen from the table, approximately 1 per cent. of apparently normal children show complete obliteration of the great fontanelle in the third trimester of post-natal life and 4.5 per cent. in the fourth trimester. From the beginning of the second year the rate of obliteration increases rapidly and by the end of the second year the fontanelle is obliterated, so far as can be determined by palpation, in over 90 per cent. of all normal cases. As the material upon which these averages are based was obtained to some extent from the poorer classes of the larger European cities it is probable that the percentages of obliteration are all somewhat low for the better nourished and more rapidly growing American children.

TABLE 2.—THE POST-NATAL INVOLUTION OF THE FRONTAL FONTANELLE (BASED ON THE DATA OF ROGER, KASSOWITZ, COHN, ROHDE AND NIKIFOROFF)

Age	Average diameter (in centimeters both sexes)	Average area (in square centimeters, males)	Average area (in square centimeters, females)	Percentage of fontanelles closed
0 to 3 months........	2.6	3.70	3.65	0.0
3 to 6 months........	2.4	3.03	2.92	0.3
6 to 9 months........	2.1	2.43	2.60	1.1
9 to 12 months........	1.8	1.55	1.45	4.5
12 to 15 months........	1.2	1.20	1.22	18.6
15 to 18 months.	0.55	1.08	0.97	46.2
18 to 21 months........	0.31	....	....	53.5
21 to 24 months........	0 08	....	...	80.0

Our data regarding the involution of the other fontanelles are much less extensive and, except for the sagittal fontanelle, are based upon observations on dried skulls. The sagittal fontanelle generally closes in the first three months of post-natal life although it may, in exceptional instances, remain open until the eighth month. The time of obliteration of the metopic fontanelle is variable but it is always completed by the end of the first year. The occipital fontanelle is already obliterated in nearly a third of all full-term newborn children and the process is usually completed by three months after birth. The sphenoidal fontanelle closes in the first six months of post-natal life. The mastoid fontanelle is generally open until the end of the first year but is always closed by 18 months. There are no data of value on the time of obliteration of the glabellar and cerebellar fontanelles.

The obliteration of the fontanelles is generally brought about by the progressive ingrowth of the edges of the membranous bones which bound them. Occasionally, however, separate ossific centers may arise in the fontanellar membranes and form distinct bones which occupy all or a part of the original fontanellar space. In these cases the obliteration of the fontanelle may be considerably hastened.

The Post-natal Development of Certain Cranial Bones.—Certain of the bones of the child's skull differ sufficiently from those of the adult to warrant brief individual descriptions.

The frontal consists of two lateral halves which are separated by a median (metopic) suture. These two masses generally begin to unite in the second year and their fusion is generally completed between the sixth and eighth years, although sometimes much later. The suture remains throughout life in about 8 per cent. of European skulls. The frontal eminences are well marked in early life while the superciliary arches and frontal spine are practically lacking.

The sphenoid, at birth, consists of three separate parts; a middle portion which represents the body, the lesser wings, and the lingulæ; and a pair of lateral masses representing the greater wings and the pterygoid processes. In about 1 newborn skull in 20, the body of the sphenoid is pierced by a small canal which extends downward from the floor of the hypophyseal fossa. This canal ordinarily contains only a small amount of connective tissue and a few small vessels, but in rare cases small nodules of hypophyseal tissue may be lodged within it. The body of the sphenoid is composed of spongy bone at the time of birth and for several years thereafter, for the sphenoidal sinus, as a rule, does not actively invade the bone in early infancy. The body and lateral masses of the sphenoid unite in the first year.

The occipital at birth consists of four bony masses: the supraoccipital, two lateral occipitals, and the basioccipital. These are arranged in a ring around the foramen magnum and are united by cartilage. The cartilage between the lateral occipitals and the supraoccipital has some flexibility at the time of birth and from its supposed movement during labor, is sometimes termed the obstetric joint. The upper and thinner part of the supraoccipital is often partially separated from the lower portion by a suture, the sutura mendosa. The supraoccipital and lateral occipitals usually begin to fuse in the second year. The lateral occipitals generally unite with the basioccipital in the third or fourth year. The fusion of all these elements may be delayed until the seventh year or even later. Ossific union between the basioccipital and the body of the sphenoid begins, as a rule, shortly after puberty and is completed early in the third decade.

Only the lateral masses of the ethmoid are formed in bone at birth. The remainder of the bone is still cartilaginous. The perpendicular plate ossifies in the first year, the cribriform plate in the second and the crista galli between the second and fourth. These three elements unite as they ossify and join with the lateral masses in the sixth year.

The mandible of the newborn consists of lateral bony halves which are united at the symphysis by a mass of cartilage. Within this cartilage are several bony particles known as the mental ossicles. The lateral halves of the bone unite in the latter part of the first or the early part of the second year. The mental ossicles usually begin to join the main bone in the first year and are always completely fused with it by the end of the third year.

The body of the mandible is relatively large at birth and its upper two-thirds is occupied by the crypts of the deciduous and certain of the permanent teeth. The rami are short and broad and are set at an angle of about 140° to the body.

There are several different concepts of the method of growth of the lower jaw and the inferior dental arch. The most generally accepted one, which is outlined here, was first developed by John Hunter and was subsequently elaborated by Tomes (the elder), Humphry, and others. According to this view, the growth of the mandible in length, *i.e.*, in the anteroposterior dimension, is brought about mainly by the apposition of bone along the hinder margin of the ramus. As bone is deposited at this point it is resorbed along the anterior margin of the ramus and the position of this structure is thus shifted backward and outward. At birth the anterior margin of the ramus lies at the level of the first permanent premolar and the germs of the permanent molars are embedded in the base of the coronoid process. With the resorption of the anterior margin of the ramus, these tooth-germs are uncovered and the posterior part of the dental arch is established. As the ramus is built up posteriorly, its form is gradually remolded and the angle between it and the body is reduced from about 140° at birth to about 130° at the end of the first period of childhood and about 120° in the adult. A smaller part of the length-increase of the lower jaw

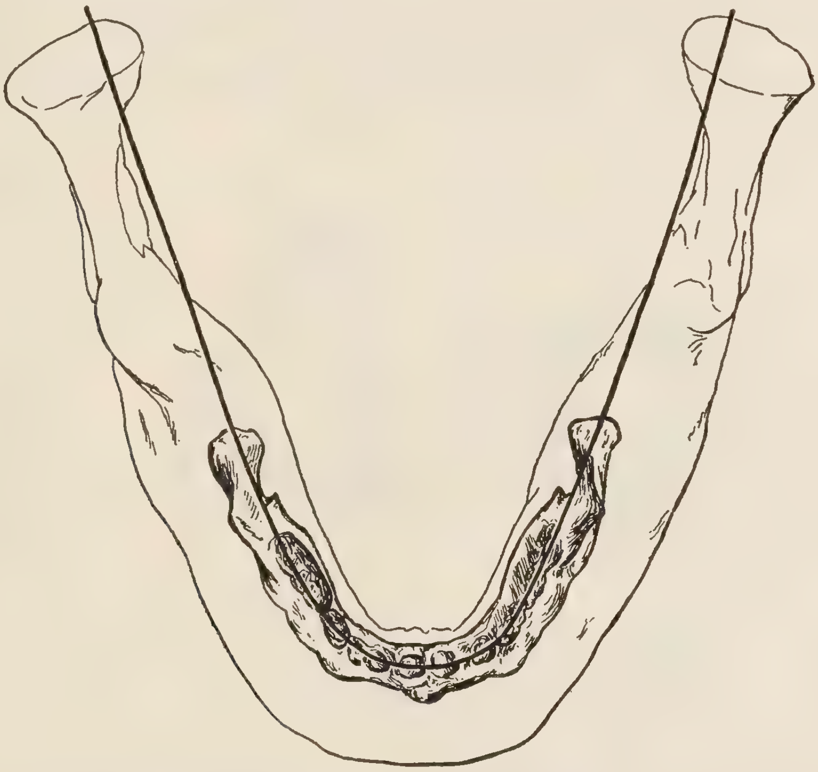

Fig. 91.—A diagram illustrating the post-natal growth of the mandible. The smaller shaded specimen is the jaw of a nine months fetus; the larger specimen, drawn in outline, is the jaw of an adult. The specimens are drawn to the same scale and are superimposed. (After Tomes, Dental Anatomy, 1898.)

takes place anteriorly through the addition of bone on the labial surfaces of the mandible and the formation of the alveolar processes.

The post-natal growth of the ramus in height takes place mainly through the addition of new bone along its superior border. The vertical increase in the body is due in part to formation of the alveolar borders and in part to the growth of its basal portion. The alveolar borders are formed as the deciduous teeth are erupted. When these teeth are shed their alveolar borders are absorbed and new borders are built up around the permanent teeth. The base of the jaw, *i.e.*, that portion lying below the level of the mental foramen, grows even more, relatively, than does the alveolar margin. This growth is due mainly to the addition of bone along the inferior margin; it takes place throughout infancy and childhood.

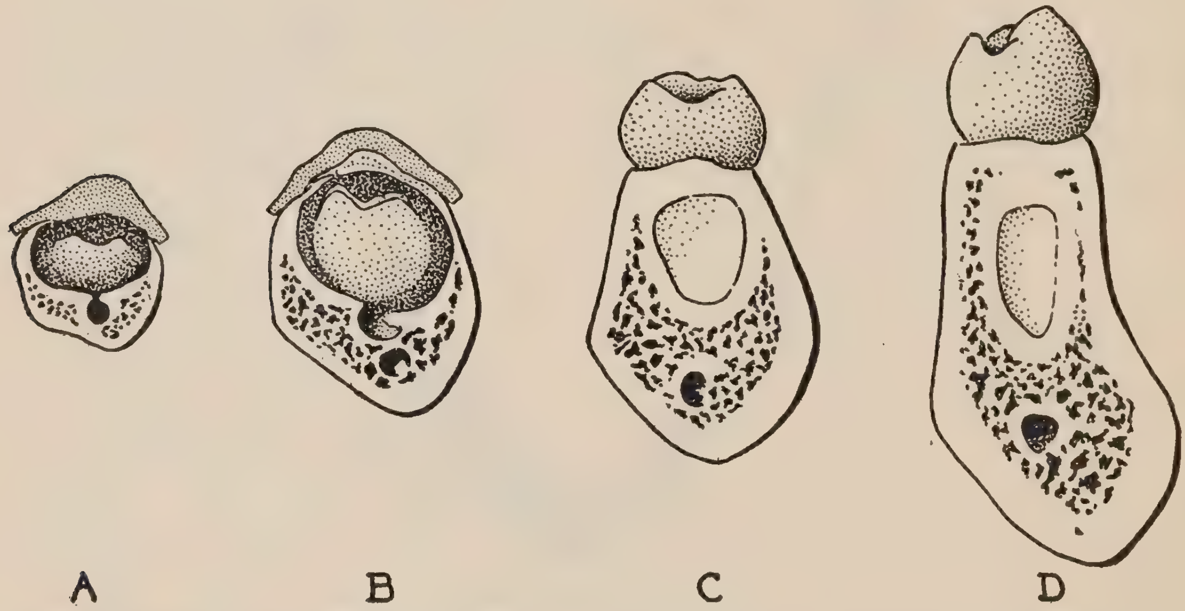

FIG. 92.—A series of sections illustrating the growth in thickness and height of the body of the mandible; the change in position of the inferior alveolar (dental) canal; and the formation of the alveolar margins. A, five months fetus; B, child at term; C, child of three years; D, adult. The sections are all taken at the level of the second deciduous molar. (After Vallois et Bennejeant.[133])

In early infancy there is some increase in the transverse diameter of the lower jaw through the formation of bone at the symphysis. However the greater part of the post-natal increase in this diameter is brought about through the deposit on the outer surfaces of the mandible and by the lateral as well as posterior growth of the rami.

The maxilla of the newborn is extremely low and broad and the frontal process is relatively larger than in the adult. The alveolar border contains five large fossæ for the deciduous teeth. A fissure, the sutura notha, extends across the palatine process from the incisive foramen to the plate of bone separating the fossæ of the lateral incisor and the deciduous canine tooth. This marks the boundary between the maxilla proper and the premaxillary bone. The infra orbital canal communicates freely with the orbit above. The maxillary sinus (antrum of Highmore) is represented by a long narrow recess on the medial side of the bone.

The post-natal growth of the maxilla is illustrated by the diagram shown in Fig. 93. The increase in the vertical diameter of the bone is due mainly to the expansion of the maxillary sinus and the development of the alveolar margins. Most of the growth in length comes about through the deposition of bone at the posterior end of the maxilla. As the maxillary sinus invades this part of the bone the permanent molars are carried downward and backward and the posterior part of the upper dental arch is established.

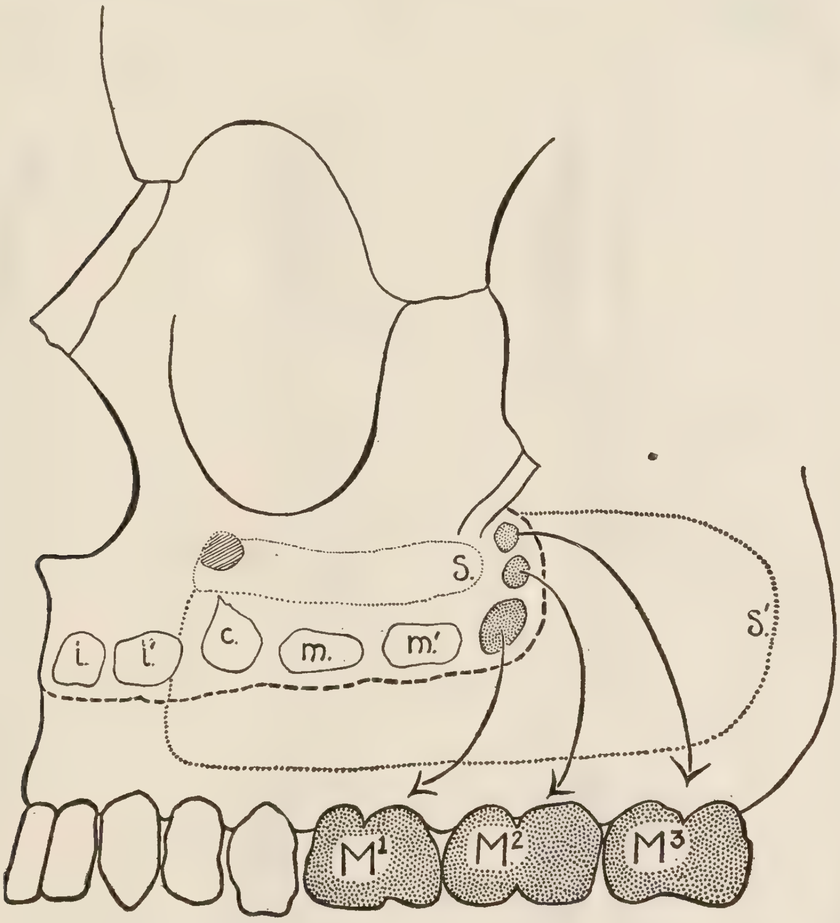

Fig. 93.—A diagram illustrating the post-natal changes in the form of the maxilla and the growth of the superior dental arch. The broken line represents the outline of the maxilla at birth. The adult bone is drawn in solid line. The permanent molars are represented in stipple. c., Deciduous canine; i.–i′, deciduous incisors; m.–m′, deciduous molars; M^1–M^3, permanent molars; s., maxillary sinus at birth; s′, maxillary sinus at maturity. (After Keith, Human Morphology and Embryology, 3rd ed., London.)

The Free Vertebral Column (Fig. 94)

The vertebral column may be divided into the free portion consisting of the cervical, thoracic, and lumbar vertebræ, which will be considered in this section; and the sacrum and coccyx which can best be described in connection with the pelvis.

The average length of the free vertebral column in the full-term newborn child is 19 or 20 cm. It is equal to approximately 40 per cent. of the total body-length. During the first two years of life it grows rapidly, increasing to about 45 cm. Thereafter the relative rate of growth becomes much slower, the vertebral column attaining a length of about 50 cm. at the time of puberty and its final length of from 60 to 75 cm. about the twenty-second year in females and the twenty-fourth year in males.

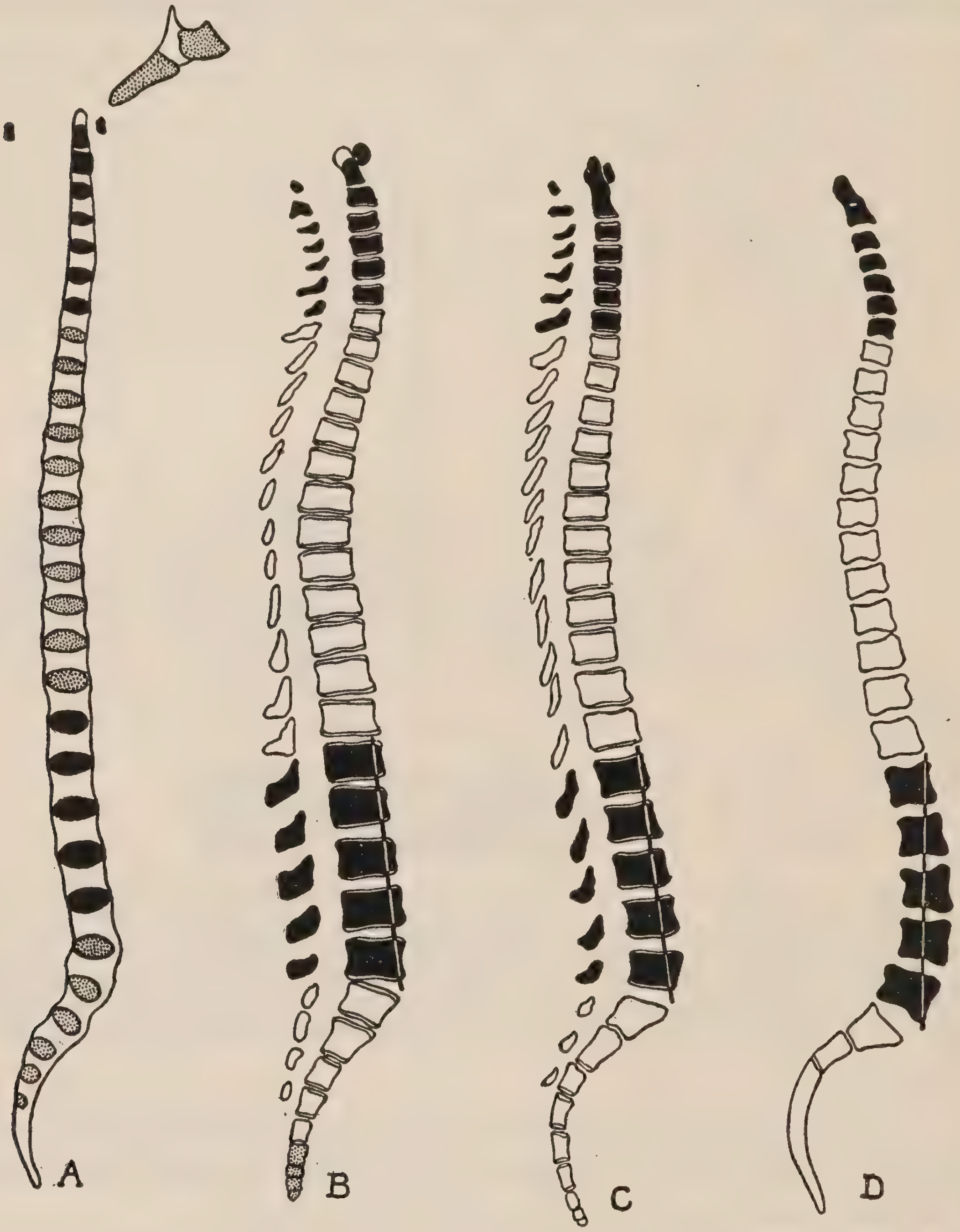

Fig. 94.—Median sections of the vertebral column at different ages illustrating the development of the normal spinal curvatures. A, newborn; B, male of six years; C, female of 13 years; D, adult male. All specimens drawn to the same size (from the axis to the top of the coccyx). The lumbar and cervical vertebræ are represented in solid black. (After Cunningham.[19])

The post-natal lineal growth of the column in childhood is due mainly to an increase in the size of the primary centers of the bodies of the vertebræ; the lineal increase after puberty is brought about mainly by the formation and growth of the epiphyses of the vertebral bodies.

The relation that the various segments (cervical, thoracic and lumbar) of the free vertebral column bear to the whole, differs somewhat in the infant and the adult. In the newborn the cervical part forms approximately one-fourth, the thoracic part one-half and the lumbar part one-fourth of the entire free spine. In the adult the thoracic portion continues to form approximately one-half of the total free spine but the lumbar portion is increased to nearly one-third and the cervical portion reduced to one-fifth or one-sixth of the whole. Thus the short thick neck of the infant is due to the abundance of adipose tissue in this region and not to its skeleton which is, in fact, relatively longer than in the adult. The time at which these relational changes take place seems to be quite variable but the process of shifting from the newborn to the adult relations is most rapid in the first three years of life.

The development of the cervical and lumbar curves of the spine is a post-natal process. In the newborn child, resting on its back, the spine forms a single gentle curve extending from the first cervical to the last lumbar vertebra, with its concavity directed anteriorly. The vertebral column at this time is still so plastic that if it is dissected free of the body it may easily be bent into a ring with the axis and the last lumbar vertebra in contact (Dwight and Rotch[5]). A cervical curve appears when the infant begins to lift its head but neither at this time nor later does it become a fixed one. The lumbar curve appears at the end of the first or beginning of the second year as the child begins to walk. It forms very slowly and throughout childhood and adolescence it may be effaced by stretching the spine. The formation of the cervical and lumbar curves is due primarily to muscular action associated with the elevation of the head and the assumption of the erect posture. Later the lumbar curve is fixed, in a measure, by the anterior thickening of the third, fourth, and fifth lumbar vertebræ and the intervertebral discs separating them. While this process begins in childhood it proceeds very slowly until maturity.

At the time of birth each typical vertebra consists of a bony body and two neural arches or lamina. These three separate osseous masses are connected with one another by hyaline cartilage, and a film of the same material covers the inferior and superior surface of the body. The two lateral masses representing the vertebral arch fuse in the medial line in the first year of life. This process begins in the vertebræ of the lumbar region and proceeds cranially. The fusion between the arches and the vertebral bodies begins in the fourth year and is generally completed by the end of the sixth. It starts with the cervical vertebræ and proceeds caudally. The epiphyses of the vertebræ appear after puberty. In the seventeenth year or later epiphyseal centers are formed in the cartilages of the transverse and spinous processes and on the superior and inferior surfaces of the vertebral bodies. A separate series of centers are also formed for the mammillary processes of the lumbar vertebræ. All of these epiphyses commonly join with the main mass of the vertebra between the twentieth and twenty-fifth year. The reader will find the regional modifications of the process of vertebral ossification described in detail by Poirier and Charpy (Traité d'Anatomie Humaine, T. I.) and by Bardeen.[18]

The atlas of the newborn consists of two osseous masses which represent the posterior arches and the lateral masses of the fully formed bone. These are united in front by a rounded bar of cartilage and behind by a thin plate of the same material. During the first year or two, centers appear in the anterior arch. The two posterior masses fuse with the anterior one in the third or fourth year; they join with one another across the posterior median line between the fifth and ninth years.

The axis or epistropheus at birth consists of two median bony masses; one in the body, and one in the odontoid process or dens; and of two lateral ones representing the vertebral arch. The lateral halves of the arch join across the posterior median line in the first year and the arch, dens, and body fuse into a single bone between the third and sixth years. A cranial epiphysis for the dens appears in the second year and a caudal one for the body in the seventh. The former joins the bone in the twelfth, the latter in the twentieth year.

The bodies of all the "typical" vertebræ more than double their diameters both transverse and sagittal, in the course of post-natal life. The growth of the bodies of the vertebra may be divided into three periods; first, from birth to three years during which from one-half to two-thirds of the entire post-natal increase occurs; second, from 3 to 16 years, a period of little if any growth; third, from 16 years to maturity during which approximately one-third of the total growth takes place. The growth of this last period is entirely epiphyseal.

THE PELVIS

The Pelvis as a Whole (Figs. 95, 96, 97, 151, 159).—The pelvis of the newborn differs from that of the adult in a number of particulars. Some of the more striking are listed below.

The general form of the newborn pelvis is distinctly conical. The length is somewhat greater in proportion to the greatest transverse and the anteroposterior diameters than in the adult.

The pelvic cavity is much smaller relatively than in the adult. It is conical or infundibulaform and the linea terminalis is poorly marked. The inlet, or superior aperture, of the lesser pelvis approaches more nearly a true circle than in later life but even at birth the transverse diameter is slightly greater than the anteroposterior. The dimensions of both the lesser pelvic cavity and the pelvic outlet are smaller in proportion to the pelvic inlet than in the adult.

The sacrum forms a greater proportion of the pelvic circumference than in the adult. It is less depressed between the ilia than in later life, and the sacral prominence is less marked and lies at a higher level. A second promontory may be indicated at the level of the linea terminalis. The sacro-pelvic angle is marked in the newborn, but the longitudinal and transverse concavities are hardly indicated.

The ala of the ilia are thick and rounded and extend upward abruptly. The iliac fossæ are present but are very shallow.

The acetabula are very large at birth but are much shallower than in later life.

The obturator (thyroid) foramina are relatively small and are placed nearer together than in the adult.

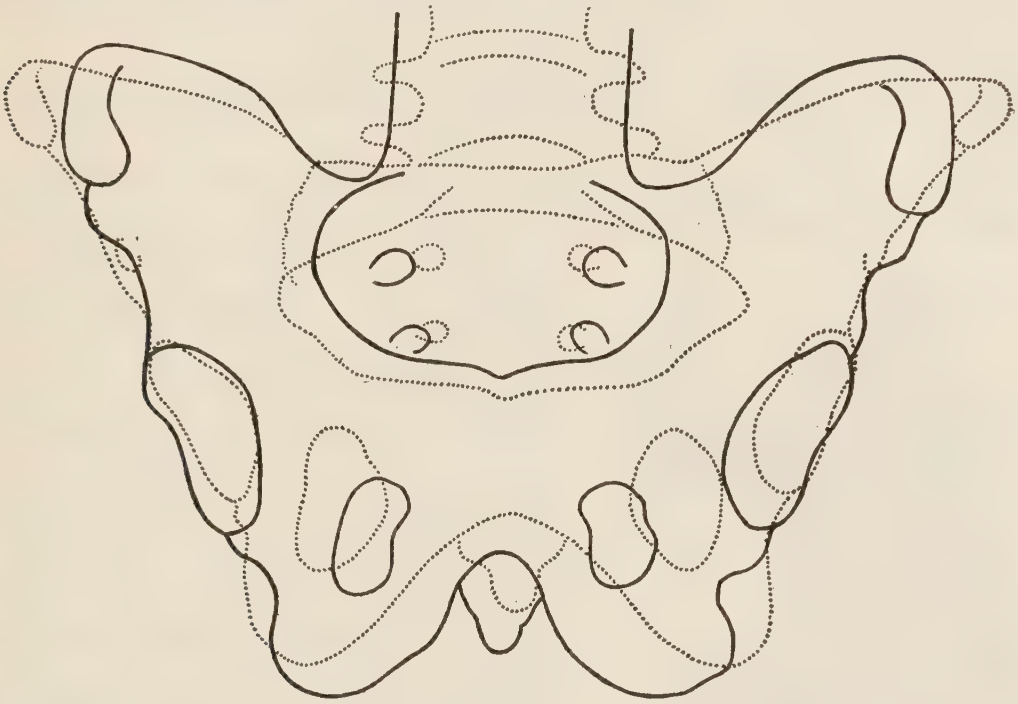

Fig. 95.—An outline drawing of the pelvis, as seen in anterior view, of a male newborn child, with the outline of an adult male pelvis drawn to the same size and superimposed upon it. The newborn pelvis is drawn at natural size and in solid line; adult pelvis is represented in broken line. (After Merkel, Handb. d. topogr. Anat.)

The pelvis is more vertical in position at birth than later. The plane of the superior aperture forms an angle of 80° with the horizontal as compared with 60° in the adult. The symphysis is also placed more vertically.

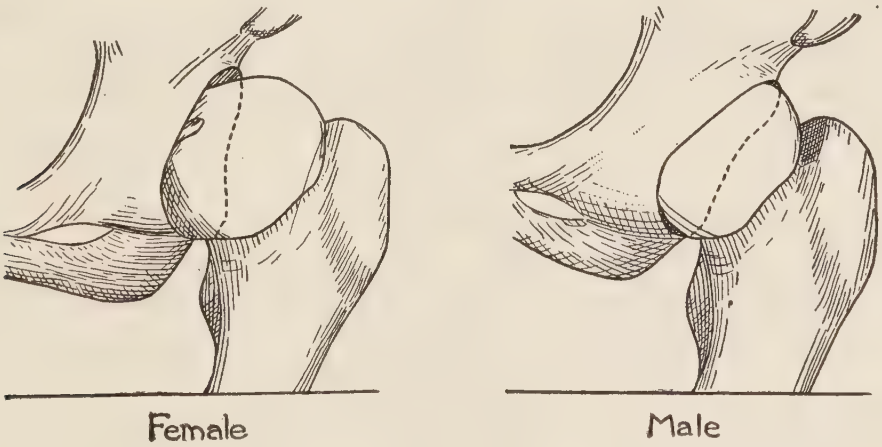

Fig. 96.—Dissections of the hip-joints of male and female newborn children showing the differences in the degree of inclusion of the head of the femur in the acetabulum in the two sexes at birth. (After LeDamany.[38])

Sexual differences in the pelvis can be made out as early as the fourth month of fetal life and are quite marked at birth. The pelvis of the newborn male is larger than that of the female; the sacrum is relatively wider; the ala are less vertical, and the subpubic angle is more acute (58° in males and 63° in females according to the measurements of Le Damany[38]). In girls, the acetabulum is almost vertical in position and only the lower part of the head of the femur is lodged in the cavity—a fact which explains the greater relative frequency of congenital dislocations of the hip in females (see Fig. 97 and further remarks under femur).

According to Hasse,[27] the bony pelvis shows a slight but constant asymmetry at birth.

During the first two years of life the pelvis grows rapidly in all dimensions. From two years to the end of the first decade the rate of growth is much less rapid. The growth rate increases again in the second decade and by the end of this time the pelvis has attained almost its adult dimensions although many of the pelvic epiphyses do not unite with their main bones until the twenty-fifth year.

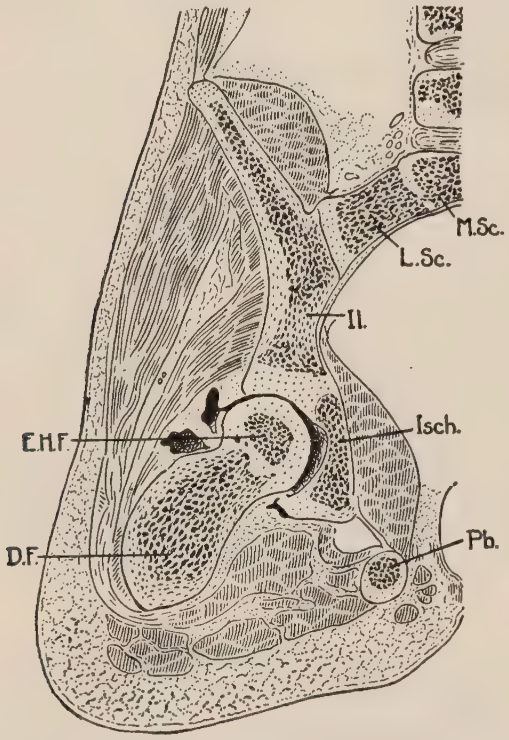

Fig. 97.—A frontal section of the right half of the pelvis of a girl nine years old. D.F., diaphysis of femur; E.H.F., epiphysis of head of femur; Il., ileum; Isch., ischium; L.Sc., lateral centers of the sacrum; M.Sc., median centers of the sacrum; Pb., pubis.

Until the infant assumes the erect position the pelvis changes very little in form. As this position becomes the habitual one the sacrum begins to descend between the ilia, and the promontory is slowly established. The increase in the transverse diameter of the pelvis is brought about mainly by the growth of the lateral parts of the sacrum and the posterior parts of the ilia. Growth also takes place along the line of apposition of the three divisions of the innominate bone in the acetabulum; but there is comparatively little growth, at least in males, at the symphysis pubis. The pelvic growth which occurs after puberty is practically all epiphyseal.

The sexual differences of the newborn pelvis, aside from that of size, are lost during the period of early rapid growth and do not reappear until after the close of the first decade. At birth and during the first decade the pelvic measurements of boys are greater than those of girls. After the tenth year the reverse is generally the case.

The growth of the pelvis as demonstrated by external measurements on normal living children is shown in Table 3 which is based upon some of the more important collections of data on the subject. The measurements in the lowest column of the table are of only limited value because of the small number of cases. The reader is recommended to the papers of Le Damany[37, 38] and Merkel[41] for recent discussions of the postnatal differentiation of the pelvis.

TABLE 3.—THE DIAMETERS OF PELVIS AS DETERMINED BY MEASUREMENTS OF LIVING CHILDREN

(Summarized from the Tables of Klein, Konikow and Tatewossoff. Averages Calculated to Nearest Millimeter)

Age	Number of cases		D. Baudeloque centimeters		D. Spinarum centimeters		D. Cristarum centimeters		D. Trochanterica centimeters	
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
Newborn	17	22	6.6	6.2	7.2	6.9	7.9	7.5	9.1	9.0
1 to 2 yrs	17	18	9.4	11.4	11.8	11.4	12.8	12.6	14.8	14.0
4 to 5 yrs	16	16	10.7	10.8	14.7	14.5	16.7	16.4	17.8	17.5
9 to 10 yrs	20	16	13.4	13.9	18.0	18.2	20.4	19.9	21.7	21.1
14 to 15 yrs	20	19	15.6	17.2	20.9	22.9	23.4	24.8	26.0	27.3
19 to 20 yrs	3	3	17.3	19.3	23.3	25.5	29.0	28.5	31.3	30.5

Ossification of the Individual Bones of the Pelvis (Figs. 84, 97, 151, 152, 155).—The innominate bone is really a complex composed of three main bones, the ilium, ischium, and pubis; one or more minor ones (the ossa acetabuli); and a number of epiphyses. The ossification center of the ilium appears in the ninth week of fetal life; that for the ischium about the middle of the third fetal month; and that for the pubis in the fourth or fifth fetal month. At the time of birth the superior ramus of the pubis, the inferior ramus of the ischium, and the greater part of the body of the ilium are formed of bone. The three bony masses are separated by a broad Y-shaped strip of cartilage which forms the greater part of the floor of the acetabulum. The rami of the ischium and pubis unite in the seventh or eighth year. The margins of the three main bones gradually encroach upon the cartilage of the acetabulum in which one or more separate ossification centers appear between the ninth and twelfth years. The three main bones and the acetabular centers join one another in the fourteenth to sixteenth year. Epiphyses for the iliac crest (three or more), tuberosity of the ischium, ischial spine, and the anterior inferior iliac spine appear soon after puberty. One or two epiphyses for the symphysis pubis appear between the eighteenth and twentieth years. The epiphyses fuse with the main mass of the bone between the eighteenth and twenty-fifth year. The later age changes in the pubic bone are discussed in detail by Todd (Am. Jour. Phys. Anthropol., III, IV).

The sacrum consists of five segments, each of which corresponds to a vertebra. These segments are separate at the time of birth and each contains five centers corresponding to the body, and the neural and the costal centers of the free vertebræ. The costal and neural centers join those of the body between the second and sixth years and the neural centers fuse medially between the seventh and fifteenth years. Epiphyses for the body of each segment appear about puberty, and those for the spine in the eighteenth year. Between the eighteenth and twentieth year a lateral epiphyseal plate, which represents a large number of fused epiphyses, is formed on either side of the sacrum. The segments of the sacrum begin to consolidate from the base upward at puberty, and the various epiphyses join the body of the bone about the twenty-fifth year. A detailed description of the development of the epiphyses of the sacrum will be found in a recent paper by Fawcett.[22]

The body of the first segment of the coccyx ossifies in the first year; that of the second between the sixth and tenth years, the third before, and the fourth after puberty. Two epiphyses are formed for each segment. The coccyx consolidates from the base upward in middle life.

THE THORAX

The Thorax as a Whole (Figs. 84, 121, 168, 169).—The thorax of the newborn has the form of a truncated cone, broad at its base and slightly flattened anteroposteriorly. The posterior wall of the thorax in the newborn is as long in proportion to the trunk as in the adult but the sternum is much shorter both in proportion to the thoracic spine and to the trunk. The superior margin of the sternum lies opposite the body of the second thoracic vertebra, while the tip of the xyphoid process is at the level of the lower part of the ninth or the upper part of the tenth thoracic vertebra. The ribs are less curved and their position is more horizontal than in the adult.

The horizontal circumference of the thorax, at the level of the nipples in newborn children with respiration completely established, is 34 to 35 cm. Linzenmeier[290] found that the average circumference in 40 full-term children before the first inspiration was 30 cm. and after the first inspiration 31.2 cm. It is evidently several days after birth before the chest increase which is dependent on the establishment of respiration is entirely completed. During the first year the circumference of the thorax increases approximately 30 per cent. and in the second year 10 per cent. Thereafter the rate of increase is much slower and it is not until the end of childhood that the horizontal chest circumference is double that of the newborn. With puberty a second period of rapid growth sets in and lasts until 19 or 20 years.

The thorax of the newborn appears almost circular in cross-section because of the relatively great antero-posterior diameter. In the early embryo the thoracic index* is as high as 185 but it declines rapidly during fetal life and at birth is about 90. In the first year it drops to approximately 80 and thereafter more slowly until at eight years it is about 70. There is little change in the index from this time until puberty when it again rises slightly and, according to the measurements of Rodes,[49] lies between 72 and 75 in early maturity. The thoracic index undergoes its greatest reduction during fetal life when gravity cannot be a factor in the change. After the child begins to walk however this force may have some influence on the reduction of the index.

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* Thoracic index.—The per cent. which the antero-posterior diameter of the thorax forms of the transverse diameter at the same level. The index is sometimes determined from measurements at the level of the nipples but more commonly from measurements at the level of the tenth rib. A detailed consideration of the changes in the thoracic index at birth will be found in a recent paper by Scammon and Rucker (Am. Jour. Dis. Child., XXI (1921) p. 552.

Ossification of the Bones of the Thorax.—At birth the sternum is a flexible strip of cartilage containing a variable number of centers of ossification. The manubrium usually contains one main center and sometimes one or two smaller ones situated below the main mass. The body consists of four segments, the ossification of which is very irregular. Often the upper segment contains a single center while the centers of the lower segments are generally paired. Ossification does not begin in the lowest segment until after birth. The segments of the sternum fuse from below upward. The process begins before puberty and is generally completed early in the third decade. Ossification of the xyphoid process begins in the second period of childhood.

The shafts of the ribs are ossified early in the fourth fetal month. The final relative lengths of the bony ribs and costal cartilages are established some time before birth. Each typical rib has three epiphyses; one for the head and two for the tubercle. These are formed about the time of puberty and join the shaft of the bone early in the third decade. The epiphyses of the tubercle join first.

Development of the Bones of the Extremities

Our knowledge of the development of the bones of the extremities has been entirely recast in recent years through the application of the Schultze and Spalteholtz clearing methods and by the use of the Röntgen ray in the study of living material. The following account is based principally on studies with these methods by Mall,[39] Bade,[17] Hasselwander,[28] Puyhaubert,[47] Freymond,[24] Pryor[44, 46] and Rotch.[52, 53]

As a considerable portion of this section deals with the formation of epiphyses and their fusion with their respective shafts in long bones, the following list of rules which have been found to apply to these processes is included here.

(*a*) The formation of the center or centers for the diaphysis always precedes the appearance of the centers for the epiphyses.

(*b*) When a bone has two epiphyses the epiphysis which is the second to ossify is the first to unite with the diaphysis (not true of the fibula).

(*c*) When an epiphysis has more than one center these centers unite with one another before they join the diaphysis.

(*d*) In long bones the first epiphysis appears in the larger extremity (not true of the ulna).

Superior Extremity (Figs. 84, 97).—The clavicle is the first bone in the body to ossify. Two centers for the shaft appear in the sixth week of fetal life and fuse almost at once. The clavicle has a single sternal epiphysis which appears between the eighteenth and twentieth years and fuses with the shaft between the twentieth and twenty-fifth years.

The main ossification center for the body of the scapula appears in the eighth week of fetal life. At birth this forms a bony plate which is surrounded, except on the axillary and superior borders, by a peripheral band of hyaline cartilage. At this time the coracoid process, a part of the acromial process, and the neck of the bone are cartilaginous. A separate center appears in the coracoid process during the first year and this fuses with the body of the bone at puberty. A small subcoracoid center appears in the tenth to twelfth year. A series of epiphyses, for the vertebral border and inferior angle, the acromium and coracoid processes, and the surface of the glenoid fossa appear between the fifteenth and eighteenth years. These join with the main bony mass between the twenty-first and twenty-fourth years.

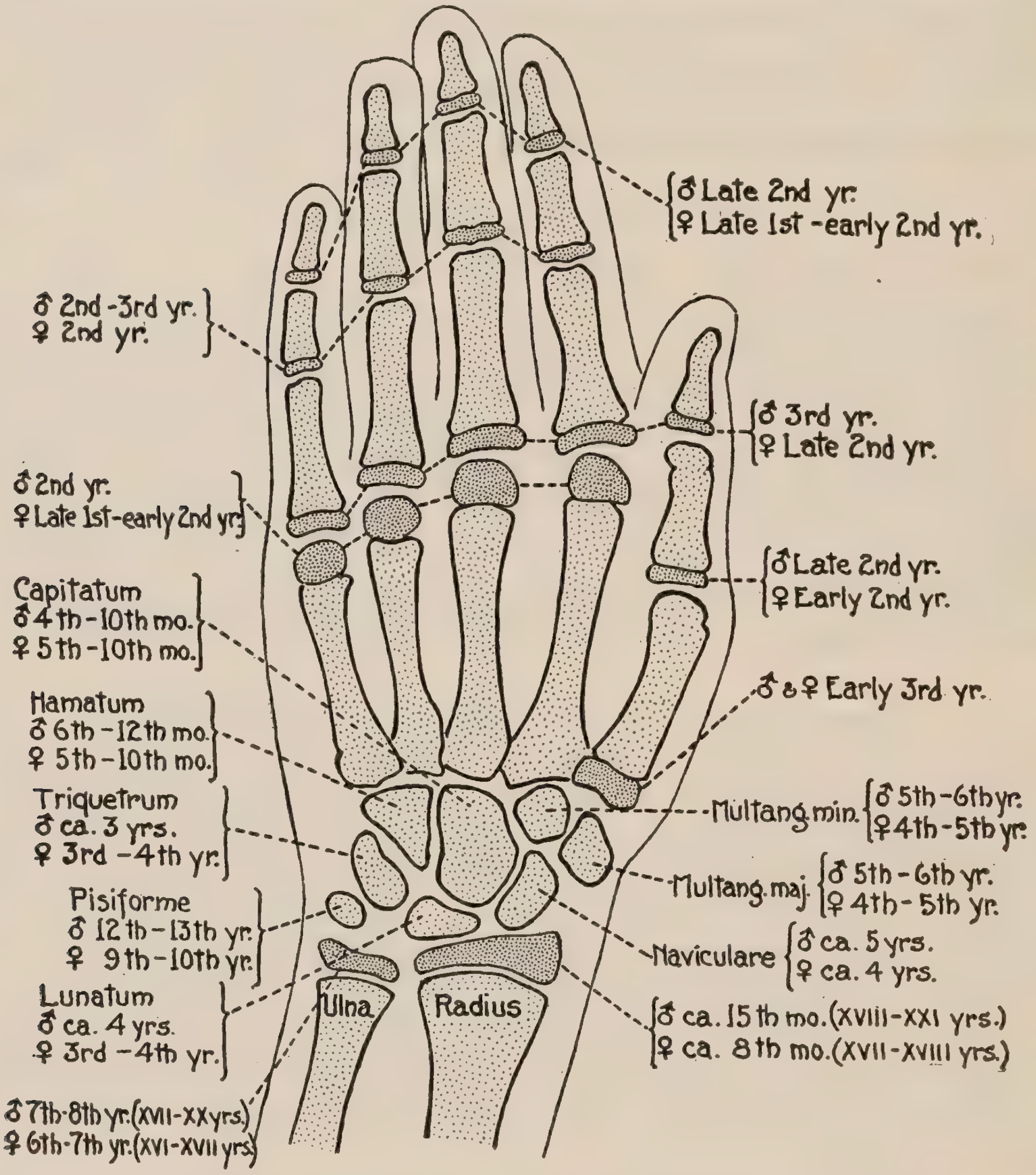


Fig. 98.—A diagram illustrating the post-natal ossification of the hand and wrist, based upon a radiograph of the hand of a girl 12 years old. Diaphyses and carpal bones in light stipple. Epiphyses in dark stipple. Dates of appearance of epiphyses indicated in Arabic numerals. Dates of fusion of diaphyses and epiphyses of the radius and ulna indicated in Roman numerals.

The shaft of the humerus begins to ossify in the sixth or seventh week of fetal life. The humerus has seven epiphyses, one for the head, one each for the greater and lesser tuberosities, and four for the inferior extremity. The epiphysis of the head appears between 6 and 20 months, that of the greater tuberosity between one and three years, and that of the lesser tuberosity between three and five years. These three epiphyses unite in the fourth or fifth year to form one mass which joins with the shaft of the bone between the twentieth and twenty-fifth years. The inferior epiphyses are the capitulum (six months to two years), median epicondylar (five and one-half to nine and one-half years), trochlear (8 to 16 years), and lateral epicondylar (11 to 18 years). The capitular, trochlear, and lateral epicondylar epiphyses first unite to form a single mass and then join the shaft. The median epicondyle joins the shaft separately in the eighteenth year.

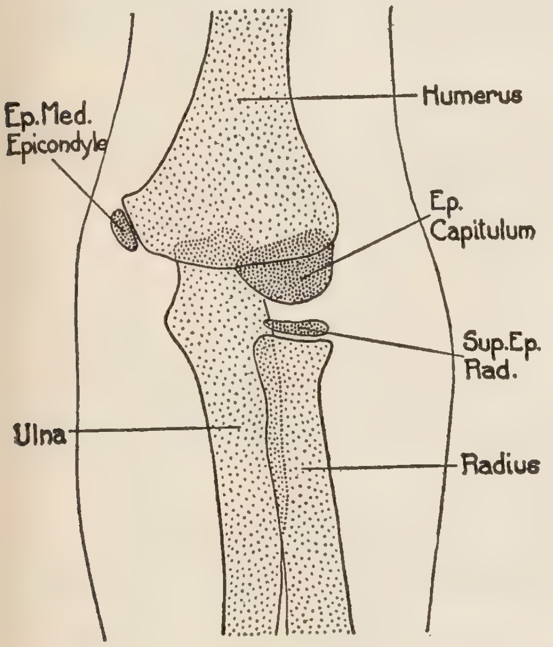


FIG. 99.—A semi-diagrammatic drawing of a radiograph of the elbow-joint of a male child of about nine years.

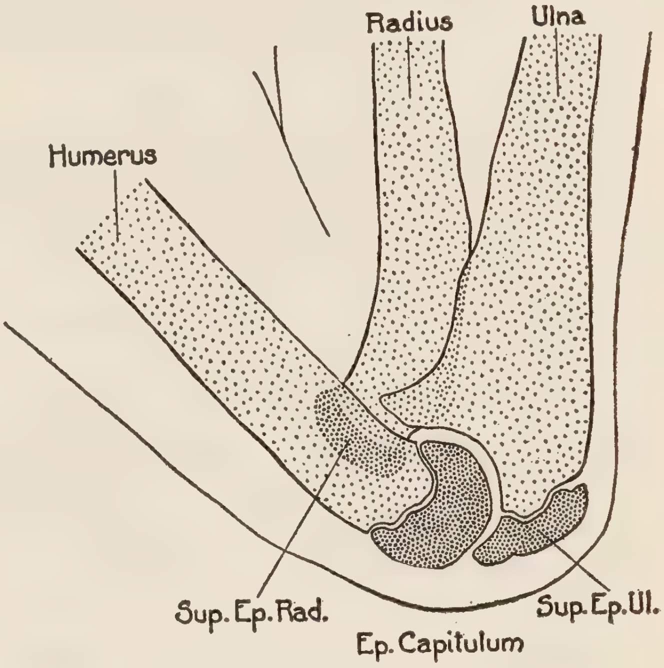


FIG. 100.—A semi-diagrammatic drawing of a radiograph of the elbow-joint of a youth of 14 years.

The center for the shaft of the ulna appears in the seventh week of fetal life. The ulna has two epiphyses, one at the carpal and one at the radial end. The carpal epiphysis appears in the sixth or seventh years in females and in the seventh or eighth years in males; it unites with the shaft between the eighteenth and twentieth years. The humeral epiphysis appears between the eighth and fourteenth years and unites with the shaft in the seventeenth year. Other epiphyses may occur in the styloid and the olecranon processes.

The center for the shaft of the radius also appears in the seventh fetal week. Both the radius and the ulna are said to be longer in proportion to the humerus in the infant than in the adult. The radius has carpal and humeral epiphyses. The former appears in females in the eighth month and in males about the fifteenth month after birth; the latter appears between four and nine years. The humeral epiphysis unites with the shaft between the seventeenth and twentieth years and the carpal between the twenty-first and twenty-fifth years.

The ossification of the carpus is generally entirely post-natal beginning in the early part of the first year and coming to an end shortly before puberty. Investigators differ considerably in their determinations of the order and date of the ossification of the carpal bones. Table 4 is a summary of the findings of more recent students of the subject. In the opinion of the writer the results of Pryor (given in the last column of the table) will be found the most valuable, for work with American children, particularly as he has taken the care to distinguish between the sexes.

TABLE 4.—TIME OF APPEARANCE OF CENTERS OF OSSIFICATION IN THE BONES OF THE CORPUS AS DETERMINED BY THE ROENTGEN-RAY

	Fuginami[26]	Puyhaubert[47]	Rotch[52]	Pryor[45, 46]	
				Females	Males
Os capitatum (magnum).	2nd mo. (end of 1st to end of 6th mo.)	Last mo. of fetal life to the close of 1st yr.	Very soon after birth	Between 3rd and 6th mos.	Between 4th and 10th mos.
Os hamatum (unciform)	2nd mo. (end of 1st to end of 6th mo.)	1st yr.	Very soon after birth	Between 5th and 10th mos.	Between 6th and 12th mos.
Os triquetrum (cuneiform)	Middle of 3rd yr. (1¼ to 3½ yrs.)	1½ to 4½ yrs.	About the 2nd or 3rd yr.	Between 2nd and 3rd yrs.	At about 3 yrs.
Os lunatum (semilunar).	Middle of 4th yr.	2½ to 6 yrs.	About the 3rd or 4th yr.	Between 3rd and 4th yrs.	At about 4 yrs.
Os naviculare (scaphoid).	Beginning of 6th yr. (beginning of 4th to end of 7th yr.)	5 to 6½ yrs.	About the 5th to 6th yr.	At 4 yrs. or early in 5th yr.	Between 4th and 5th yrs.
Os multangulum minus (trapezoid).	Beginning of 6th yr.	4½ to 6½ yrs.	About the 6th to 8th yr.	Between 4th and 5th yrs.	Between 5th and 6th yrs.
Os multangulum majus (trapezium)	Beginning of 6th yr.	3½ to 6 yrs.	About the 5th yr.	Between 4th and 5th yrs.	Between 5th and 6th yrs.
Os pisiforme.........	Beginning of 12th yr.	10 to 14 yrs.	About the 12th yr.	Between 9th and 10th yrs.	Between 12th and 13th yrs.

There appears to be a large amount of variation in both the time and order of the ossification of the carpal bones even in normal children. Pryor[45] summarizes his results, based on the study of 554 children, as follows:

(*a*) "The bones of the female ossify in advance of the male. This is measured at first by days, then months, then years.

(*b*) "The bones of the first child, as a rule, ossify sooner than those of subsequent children.

(*c*) "Regardless of the variations (normal) the ossification is bilaterally symmetrical.

(*d*) "Variation in the ossification of bones is a heritable trait."

The degree of variation in the order of the carpal bones as well as in the carpal complex at different ages is shown in Table which is based upon a numerical summary of Pryor's cases. Most investigators other than Pryor have found that the ossification of the multangulum majus (trapezium) precedes that of the multangulum minus (trapezoid).

The variation in the time of ossification of the carpal bones is illustrated in the following table by Brice based upon the data of Puyhaubert.[47]

All the carpal bones commonly ossify from a single center. However cases of two centers have been reported for the naviculare (scaphoid), lunatum (semilunar), triquetrum (cuneiform), hamatum (unciform), multangulum majus (trapezium) and pisiforme.

The centers for the diaphyses of the metacarpals and phalanges appear in the ninth week of fetal life. Ordinarily epiphyses are formed only at the distal ends of the metacarpals although proximal epiphyses for the first and second metacarpals are present occasionally. The epiphyses of the phalanges are all proximal. The epiphyses of the long bones of the hand are formed between the latter part of the first and the latter part of the third year. The epiphyses of the metacarpals unite with their shafts between fifteen and twenty years. Those of the phalanges fuse with their shafts between the eighteenth and twentieth years.

The ossification of the sesamoid bones of the hand generally begins at puberty.

Inferior extremity (Figs. 96, 97, 101, 102, 103.)—The femur has four epiphyses; one for the inferior extremity, one for the head, one for the greater trochanter, and one for the lesser trochanter. The inferior epiphysis is generally present at birth; the epiphysis for the head appears between six months and two years after birth; that of the trochanter major between three and one-half and six years; and that for the trochanter minor between 7 and 11 years. The epiphyses unite with the shaft in the reverse of the order of their appearance; the lesser trochanter in the seventeenth year, the greater trochanter in the eighteenth, the head in the eighteenth or nineteenth, the inferior from the eighteenth to twenty-second year.

The shaft of the femur at birth is quite straight, whereas in the adult it is always bent in a gentle arch with its concavity directed backward. This bend is acquired during childhood with the assumption of the erect posture. At birth and for some time thereafter the neck of the femur is very short and forms a much more acute angle with the shaft than in the adult. During the latter part of fetal life the femur undergoes a high degree of torsion so that in the newborn the angle between the axis of the head and neck, and the transverse axis of

TABLE 5.—THE ORDER OF OSSIFICATION OF BONES OF THE CARPUS IN PERCENTAGES OF FREQUENCY (Based upon the Data of Pryor.[47] To Find the Order Frequency of a Given Bone Read the Left Hand Figures from above Downward. To Find the Frequency of all Bones in a Given Order Read the Figures in Parentheses from Left to Right. Percentages are Calculated to the Nearest Whole Numbers)

Order	Os capitatum (magnum)	Os hamatum (unciform)	Os triquetrum (cuneiform)	Os lunatum (semilunar)	Os naviculare (scaphoid)	Os multangulum minus (trapezoid)	Os multangulum majus (trapezium)	Os pisiforme (pisiform)
First	98 (98)	2 (2)						
Second	2 (2)	98 (98)						
Third	......	......	96 (96)	4 (4)				
Fourth	......	......	4 (5)	86 (86)	2 (1)	6 (4)	6 (3)	
Fifth	......	......	......	4 (5)	62 (52)	29 (24)	25 (19)	
Sixth	......	......	......	1 (2)	21 (23)	48 (50)	26 (26)	
Seventh	......	......	......	3 (6)	15 (20)	17 (22)	43 (52)	
Eighth	......	......	......	......	......	......	......	100

TABLE 6.—OSSIFICATION OF CARPUS (Tabulated by Brice, Quain's Anatomy, 11 ed., from the Data of Puyhaubert[47])

Bones	Percentage of cases in which ossification centers are present at							
	Birth	1st yr.	2nd yr.	3rd yr.	4th yr.	5th yr.	6th yr.	7th yr.
Os capitatum (magnum)	20	100	100	100	100	100	100	100
Os hamatum (unciform)	20	100	100	100	100	100	100	100
Os triquetrum (cuneiform)	..	...	20	50	80	100	100	100
Os lunatum (semilunar)	..	...	...	20	30	36	80	100
Os multangulum majus (trapezium)	..	...	...	...	8	1	70	100
Os multangulum minus (trapezoid)	..	...	...	...	...	1	70	100
Os naviculare (scaphoid)	..	...	...	...	...	1	60	100

the body of the bone is 36.5° in the right femur and 32.4° in the left. In the adult the angle is from 8 to 10°. It seems probable that congenital dislocations of the hip are the result of this torsion and that their greater frequency on the right side can be explained on the basis of the preceding figures. The degree of torsion in the femur of females is slightly greater than that of males; and this, together with the differences in the acetabula already mentioned, probably accounts for the higher percentage of congenital dislocations in girls than in boys.

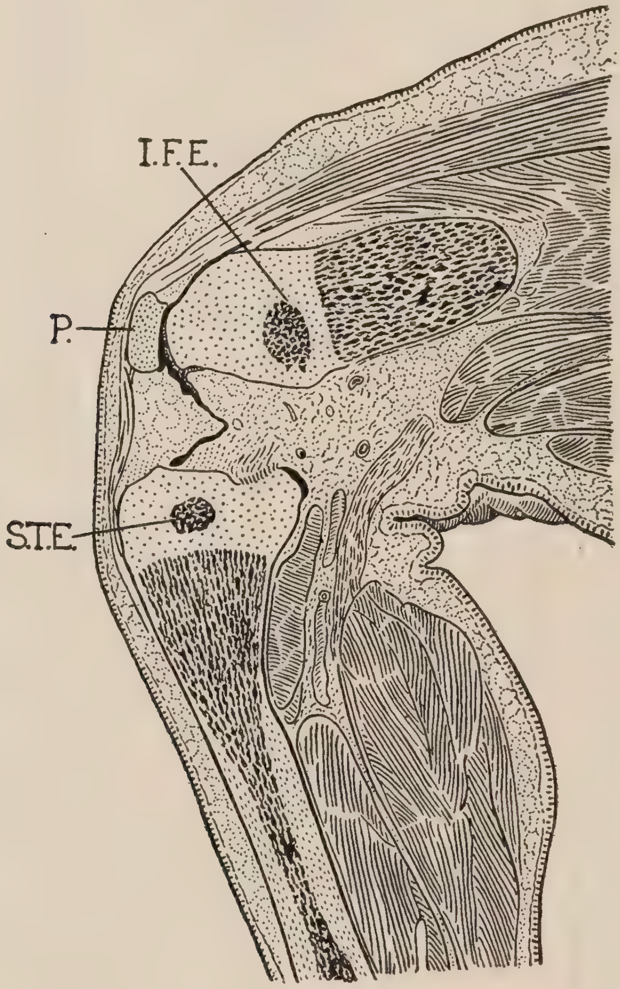


Fig. 101.—Median section of the left knee of the newborn male child 54 cm. long. I.F.E., inferior femoral epiphysis; P., patella; S.T.E., superior tibial epiphysis. Natural size.

The tibia has two constant epiphyses for the superior and inferior extremities, and generally one for the tubercle as well. The superior epiphysis is generally present at the time of birth and joins the shaft between the seventeenth and twenty-fourth years. The inferior epiphysis appears between the sixth and fifteenth post-natal months and fuses with the shaft between 16 and 19 years. The tuberosity of the tibia is commonly formed in part from a downgrowth from the superior tibial epiphysis, and in part from a small separate center lying just below this process. A second center may be present. The time of formation of the separate center is extremely variable. Its presence in the first year has been reported but it commonly appears between the seventh and fifteenth years. It usually joins with the process of the superior epiphysis between the twelfth and fifteenth years. Fusion with the shaft of the tibia takes place along with that of the superior epiphysis between the seventeenth and twenty-fourth years (Kirchner).[33]

Because of the importance of the inferior femoral and superior tibial epiphyses in determining the maturity of the newborn infant I include a summary of the recent work of Pozier[44] on this subject. This author examined the knees of 166 newborn children by means of the Roentgen ray. His conclusions were; (1) the same number of centers are found in the right and left members of any newborn; (2) if a single center is present it is always the inferior femoral epiphysis; (3) there is no direct relation between the development of the ossification centers at the knee and body-weight; (4) the inferior femoral epiphysis generally appears at the beginning of the last fetal month and the superior tibial epiphysis in the week preceding birth; (5) all children with two centers, weighing 2,700 gm. or more and measuring 47 cm. or more in length are full-term; (6) children with two ossification centers weighing 2,600 gm. or less and measuring 44 cm. or more are at term or nearly so; (7) all children with one center weighing 2,800 gm. and measuring 44 cm. or more are full-term or nearly so; (8) all children with two centers are at least eight and one-half months; (9) all infants weighing less than 2,500 gm. and without ossification centers are less than full-term. The following is a tabular summary of Pozier's data. A further discussion of this subject is given by Adair and Scommon (Am. Jour. Obstet. and Gynecol., II (1921).

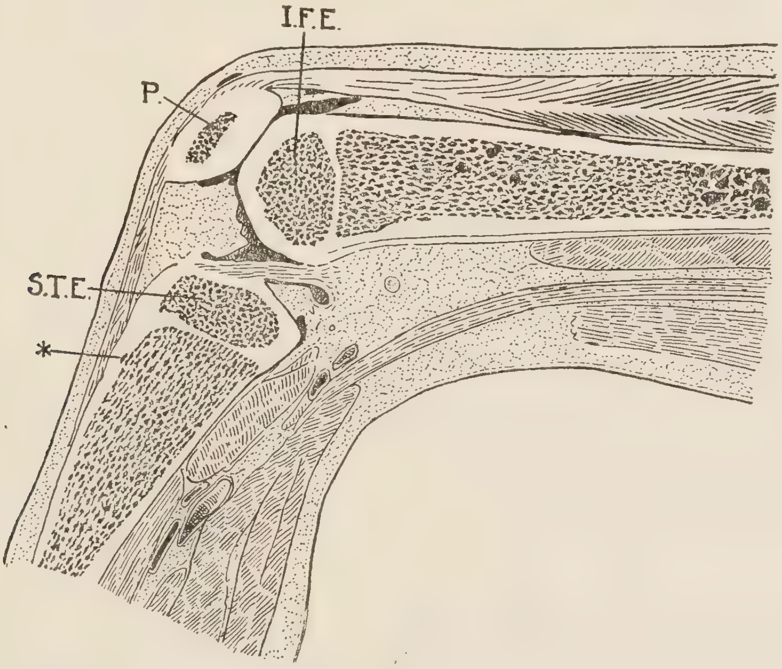


FIG. 102.—Median section of the knee of a female child nine years of age. I.F.E., inferior femoral epiphysis; P., patella; S.T.E., superior tibial epiphysis. *Accessory epiphysis for tubercle of the tibia. One-half natural size.

TABLE 7.—THE DEVELOPMENT OF THE OSSIFICATION CENTERS OF THE KNEE (AFTER POZIER[44])

Age in weeks calculated from last menstruation	Number of cases	Percentage of cases in which:		
		No center is present	One center only is present	Two centers are present
33 to 35	7	57	43	0
35 to 37	12	17	42	42
37 to 39	15	27	33	40
40th	34	3	32	59
40 to 42	54	6	30	65
42 and over	19	0	16	84
Total	141			

The fibula has an inferior and a superior epiphysis. An inferior epiphysis appears between 15 months and 2½ years and a superior epiphysis between three and one-half and six and one-half years. The superior epiphysis joins the shaft between 20 and 22 years and the inferior between 22 and 24.

The ossification center of the patella appears between three and six years.

Bones of the Foot.—Although the development of the tarsus has not been studied in the same detail as has that of the carpus there is a considerable amount of data upon the subject. Unlike the carpal bones, which are commonly all cartilaginous at birth, two bones of the tarsus, the calcaneus and the talus (astragalus) always possess ossification centers in the full-term newborn; and a third bone, the cuboid, is ossified in over one-half of the cases. All observers are agreed as to the customary order of the tarsal bones, which is as follows: (1) calcaneus, (2) talus (astragalus), (3) cuboid, (4) third or external cuneiform, (5) first or internal cuneiform, (6) second or middle cuneiform, and (7) navicular (scaphoid). The time of appearance of these centers of ossification is indicated in the following table which is the summary of the more important studies on the subject.

Several of the tarsal bones arise from more than one ossification center. The calcaneus often has a periosteal center which arises a little earlier than the main center and generally soon fuses with it. The talus, cuboid and first (internal) cuneiform may also form from several centers which fuse shortly after their appearance. The navicular commonly has a secondary smaller lateral center which appears shortly after the main one and fuses with it before puberty.

The calcaneus is the only tarsal bone having an epiphysis. This is formed, sometimes from several centers, between the sixth and tenth years and generally joins with the main mass of the bone shortly after

TABLE 8.—TIME OF APPEARANCE OF CENTERS OF OSSIFICATION IN THE BONES OF THE TARSUS AS DETERMINED BY THE ROENTGEN RAY

	Bade[17]	Hasselwander[28]	Freymond[24]	Rotch[52]	Puyhaubert[47]
Calcaneus (main centers)	End of 6th fetal mo. or beginning of 7th.	Periosteal center 4½–5 fetal mo. Main center 6 fetal mos.	....	6th fetal mo.	
Calcaneus (epiphysis)	....	8 yrs.	....	9th yr.	6 to 9 yrs.
Talus (astragalus)	End of 7th or beginning of 8th fetal mo.	7th fetal mo.	....	7th fetal mo.	
Cuboideum	After birth	Last fetal mo.	1st half of 1st yr.	9th fetal mo.	Last fetal to 6th post-natal mo.
Naviculare	....	3½ yrs.	2nd to 3rd yr.	4th yr.	External center 2½ to 3½ yrs. Internal center 4 to 5½ yrs.
Cuneiform III	Between birth and 6 mos.	5 to 6 mos.	End of 1st yr.	1st yr.	6 to 18 mos.
Cuneiform I	16th mo.	3 yrs.	End of 2nd yr.	3rd yr.	1½ to 2½ yrs.
Cuneiform II	2 to 2½ yrs.	3 yrs.	End of 2nd or beginning of 3rd yr.	4th yr.	2½ to 3½ yrs.

puberty. Occasionally fusion takes place immediately after the formation of the epiphyseal center.

As a rule the tarsal bones ossify earlier in girls than in boys.

The shafts of the metatarsals ossify about the end of the second fetal month. The epiphysis of the first metatarsal is proximal to the shaft but all of the others are distal. Occasionally the first metatarsal may have a distal epiphysis as well, and a separate center may be formed for the tuberosity of the first metatarsal. The epiphyses appear in the latter part of the third year. Ossification begins in the medial metatarsal epiphysis and proceeds laterally. The epiphyses unite with the shafts between the fourteenth and nineteenth years in females and between the seventeenth and twenty-first years in males.

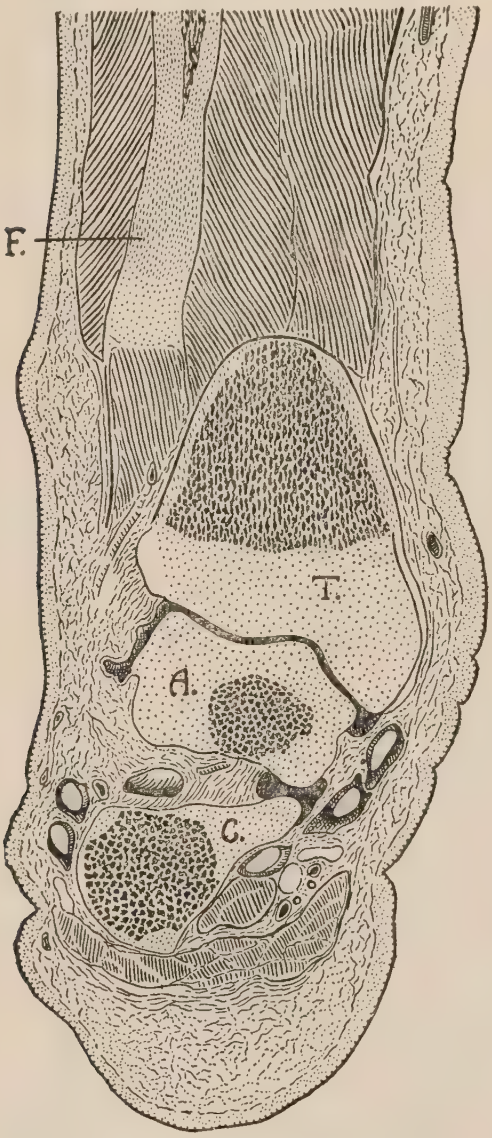


Fig. 103.—Vertical section of the ankle of the newborn male child, 54 cm. in length. A., astragulus (talus); C., calcaneus; F., fibia; T., tibia.

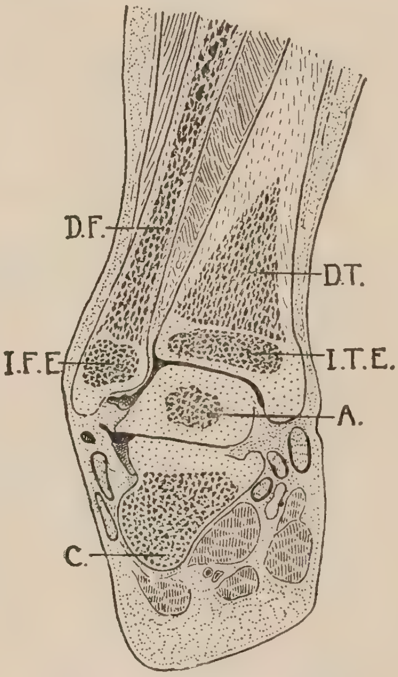


Fig. 104.—Vertical section of the ankle of a girl nine years old. A., astragulus (talus); C., calcaneus; D.F., diaphysis of fibula; D.T., diaphysis of tibia; I.F.E., inferior epiphysis of fibula; I.T.E., inferior epiphysis of tibia.

The shafts of the phalanges are ossified in the third fetal month. The epiphyses, which are proximal in position, are formed in the third and fourth years. They appear first in the proximal row and last in the distal row of phalanges. The period of union of the epiphyses with their shafts extends from the twelfth to the twenty-first year. The epiphyses of the distal row of phalanges are the first to unite with their shafts and the proximal row are the last. The process takes place earlier in females than in males.

The sesamoid bones of the great toe appear in the eighth year in females and in the eleventh year in males.

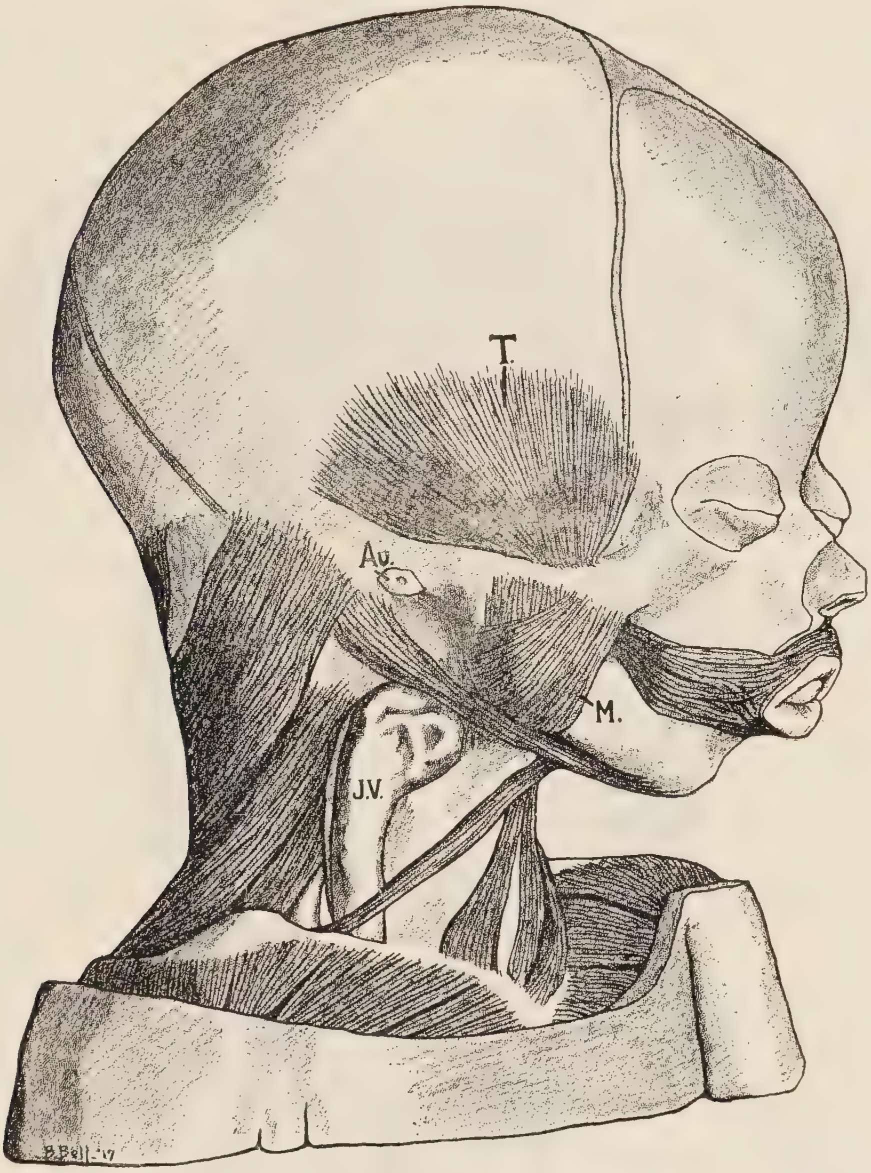


Fig. 105.—Lateral view of the musculature of the head and neck of a full-term newborn child. (Drawn from a dissection and cast by Dr. J. C. McKinley.) Au., auricle; J.V., jugular vein; M., masseter muscle; T., temporal muscle.

Skeleton of the Foot as a Whole.—In the early part of fetal life the foot is strongly inverted. About the seventh fetal month a process of gradual eversion begins but at birth and for some time thereafter some inversion is still noticeable. Eversion is brought about by profound changes in the shape of the calcaneus and talus, and by the rapid growth of the bones forming the medial border of the foot. At birth the foot also has a greater degree of dorsoflection than in later life, due to the greater relative area of the trochlea of the talus. Ventral flexion, however, is limited by the shortness of the dorsal extensor muscles.

If an impression be made on smoked paper or glass of an infant's foot, almost the entire plantar area is outlined and a picture is secured quite similar to that seen in cases of flat foot in the adult. Definite transverse and longitudinal plantar arches are present, however, even at the time of birth; and the latter is higher relatively than in the adult. The arches are concealed in the impressions by the thick pad of plantar fat which acts as a support until the posterior leg muscles and plantar fascia take over this function. Dane,[20] who measured the longitudinal plantar arch in a number of infants, found both an absolute

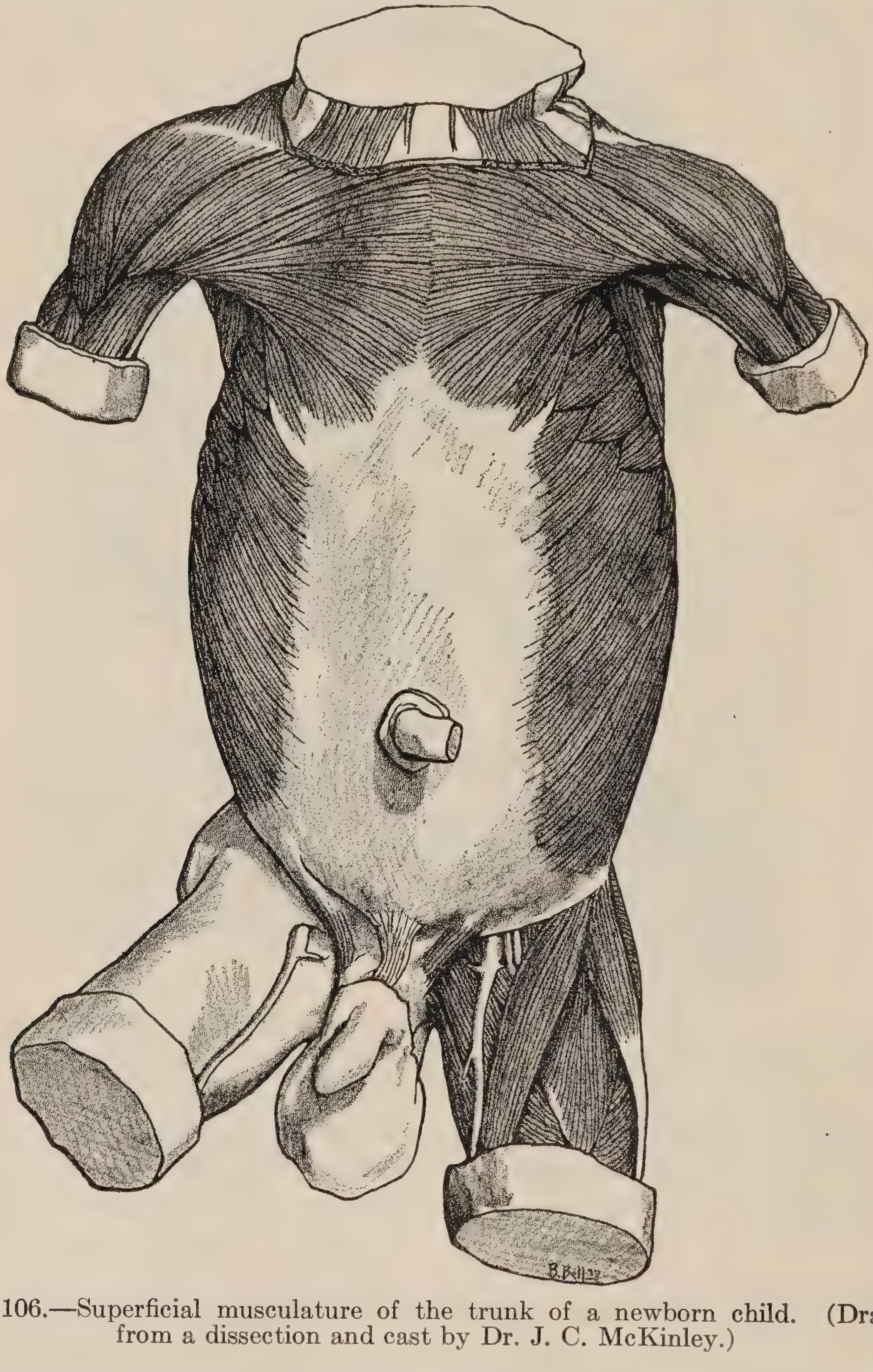


Fig. 106.—Superficial musculature of the trunk of a newborn child. (Drawn from a dissection and cast by Dr. J. C. McKinley.)

and relative decrease in the height of the arch during the second year of life, in the period when the child first begins to bear its weight upon its feet.

THE MUSCULATURE (Figs. 105, 106, 111)

We know comparatively little regarding the post-natal development of the muscular system. According to the observations of Theile[65] and others, the muscles form about one-fourth of the entire body weight at birth. Apparently the muscles do not grow as fast as the remainder of the body during infancy but in later childhood they increase so rapidly that at puberty, as in later life, they form 40 to 45 per cent. of the total body weight. The absolute gain in the weight of the musculature between birth and maturity varies greatly in different individuals but generally it is nearly forty-fold or about twice that of the body as a whole.

In the newborn the muscles of the head and trunk form a little over 40 per cent. of the total weight of the musculature while in maturity they form from 25 to 30 per cent. During childhood the muscles of the inferior extremities increase from a little over 40 per cent. to about 55 per cent. of the total weight of the musculature. The muscles for the superior extremities form from 18 to 20 per cent. of the entire musculature throughout post-natal life.

The growth of skeletal muscles during post-natal life apparently is due almost entirely to the increase in volume of the individual fibers and not to an increase in their number. MacCallum[60] estimates that the muscle fibers of the sartorius increase about 10 per cent. in number and about 800 per cent. in area in cross-section between birth and maturity.

The literature contains a few scattered observations regarding the topography of certain of the muscles during childhood but the subject as a whole is practically untouched. Through the kindness of Dr. J. C. McKinley I am able to reproduce here two figures of the musculature of the newborn child which are a part of his forthcoming monograph on the subject (Figs. 105, 106).

The submuscular and subfascial bursæ and the mucous sheaths of the tendons of the various muscles are practically all fully developed at the time of birth. The subcutaneous bursæ are more variable and may or may not be completely developed in the newborn. When absent at birth they develop in the course of the first few years. For details regarding their condition in the newborn and their later development the reader is referred to the papers of Heincke[59] and Whittaker.[63]

THE DIGESTIVE SYSTEM

THE MOUTH AND TONGUE (Figs. 107, 108)

The lips of the newborn and young infant show two anatomical modifications fitting them for the act of sucking. The red part of the mucosa is differentiated into two zones—an external smooth one, the pars glabra, and an internal one which is studded with long pointed papillæ and is known as the pars villosa. The papillæ not only cover the pars villosa of the lips but extend backward in an irregular band along each cheek nearly to its posterior margin. In the mid line of the upper lip in the pars villosa is a distinct elevation—the superior labial tubercle. Both the tubercle and the papillæ of the pars villosa ordinarily disappear in the first few months but either may persist to some degree in adult life.

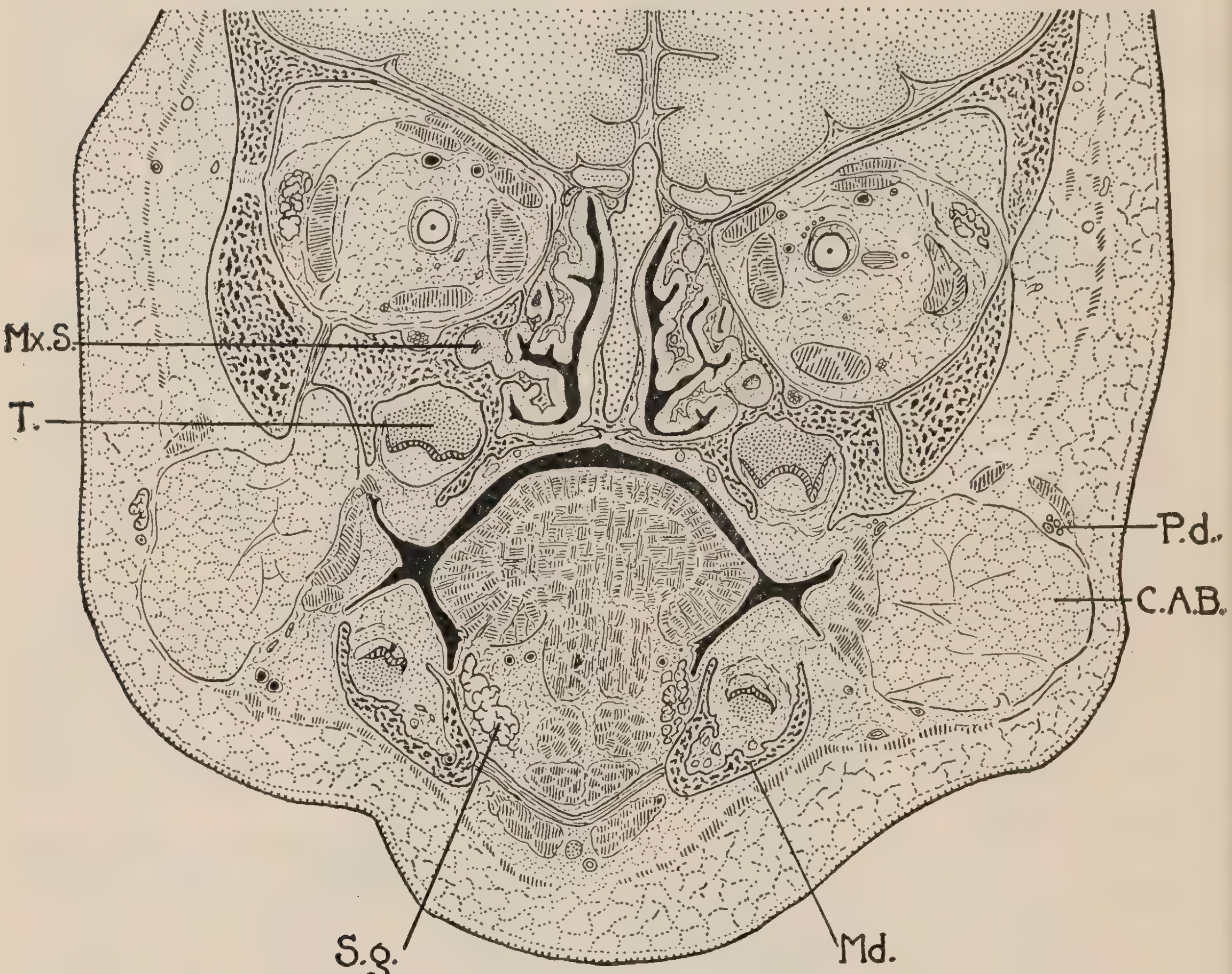


Fig. 107.—Frontal section of the face of a full-term newborn child. C.A.B., corpus adiposum buccæ (sucking pad); Md., mandible; Mx.S., maxillary sinus; P.d., parotid duct; S.g., sublingual gland; T., germ of molar tooth. Natural size.

The oral cavity of the infant is only a potential one for when the mouth is tightly closed the tongue comes in contact with the gums laterally and with the roof of the mouth above. When the mouth assumes the position for sucking there are formed three cleft-like spaces through which fluids can be carried to the pharyngeal cavity. A median cavity, the Cavum suctorium of Hasse,[92] lies between the dorsum of the tongue below and the hard palate above, and opens into the cavity of the isthmus of the fauces through a narrow aperture on either side of the soft palate. The two lateral cavities are arcuate clefts bounding the lateral and medial surfaces of the gums respectively. They communicate freely since the upper and lower gums are not completely in contact in the newborn child or the suckling. Fluids from these lateral spaces enter the cavity of the isthmus through a cleft between the lateral margin of the tongue and the anterior pillar of the fauces (glossopalatine arch). In the suckling the cavity of the isthmus is closed off from the oropharynx except for two small lateral openings which are bounded by the epiglottis, the soft palate, and the posterior pillars of the fauces (arcus). These two apertures are in front of the opening of the larynx and are partly separated from it by the posterior palatine arches so that fluids may pass into the pharynx and esophagus without entering the cavity of the larynx.

The hard palate of the young child is low, broad and short. Generally it is corrugated by a series of five or six irregular transverse folds. These structures are very much more prominent in the fetus than in the child and may be either entirely obliterated or broken up into mound-like elevations before maturity. Possibly they assist in holding the nipple during the sucking act. A small conical projection, the incisive papilla, occurs at the middle of the anterior margin of the palate. Along the median line of the palate in the newborn there occur a series of epithelial masses or pearls, which often form whitish rounded elevations on the surface of the mucosa. According to Epstein,[83] these are epithelial debris which are left behind in the union of the halves of the hard palate.

The tongue of the infant is relatively short and broad. The sulcus terminalis which indicates the division between the oral and pharyngeal portions of the organ is well marked and the foramen cæcum is generally a large distinct pit. All the types of lingual papillæ recognized in the adult are present before birth. Taste buds are present on the vallate, foliate, and fungiform papillæ of the newborn and in the epithelium of the foramen cæcum. They are said to increase considerably in number during the first year of life. The lymphoid follicles of the lingual tonsil are formed in the ninth or tenth fetal month. These are relatively more numerous in the child than in the adult.

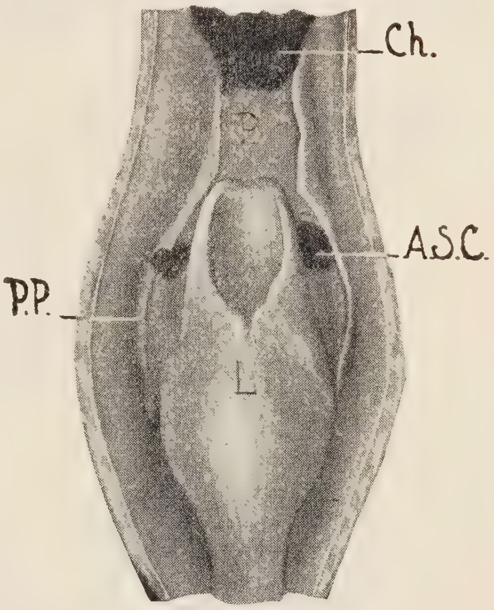
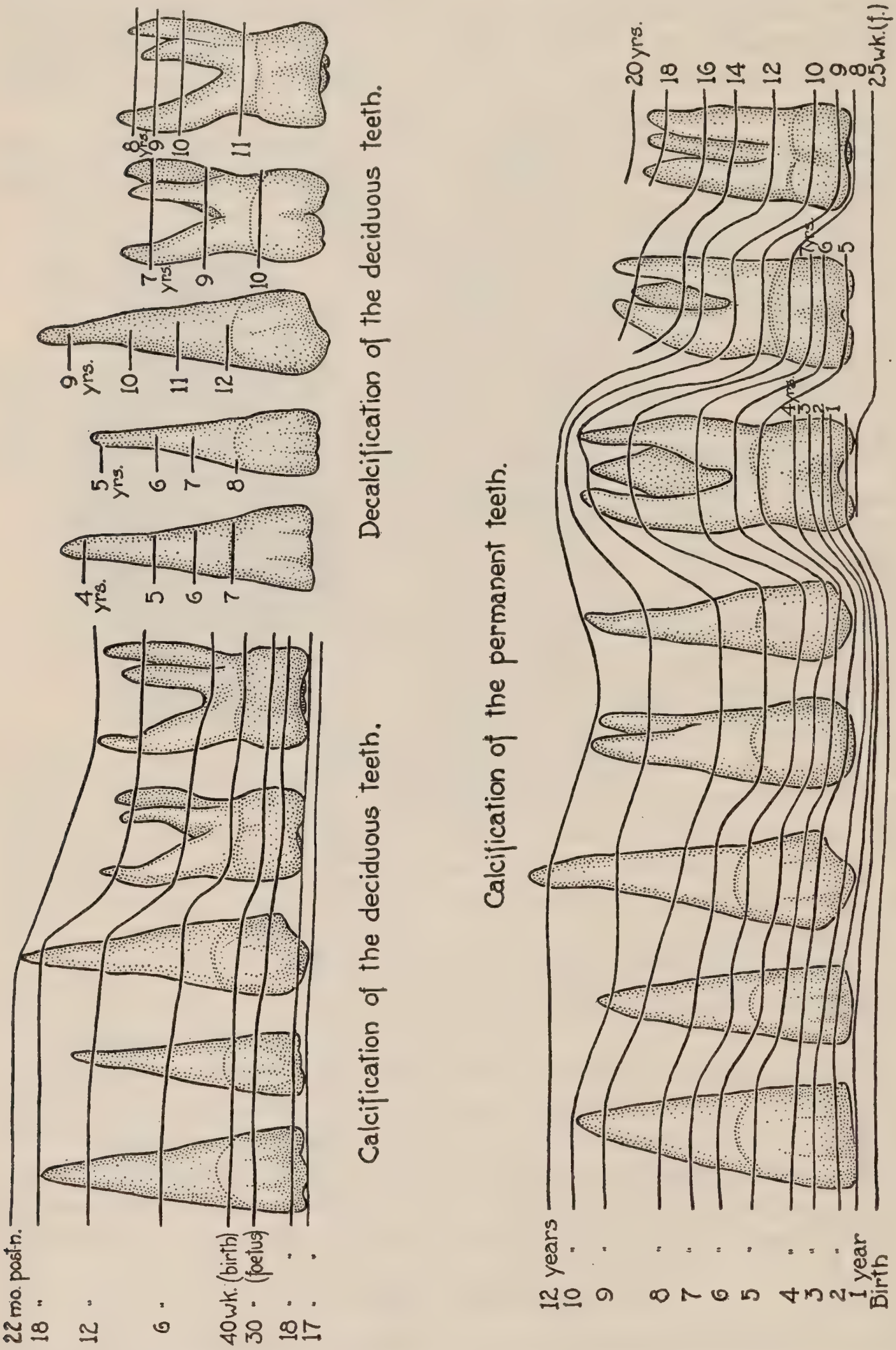


Fig. 108.—Posterior view of the anterior wall of the pharynx of a newborn child. A.S.C., posterior aperture of salivary space (apertura salivariæ commune); Ch., posterior choanæ; L., larynx; P., soft palate; P.P., posterior palatine pillars. (After Hasse.[92])

The Sucking Pad (Figs. 107, 111)

In either cheek of the newborn child there is a sharply circumscribed mass of adipose tissue known as the sucking pad or bolus of Bichat (corpus adiposum buccæ). The main mass of this fatty body lies in the space between the buccinator and masseter muscles and is covered externally by the facial muscles and fascia. From this more superficial portion a process extends backward and inward to join the temporal fat-mass. The superficial portion is from 1.5 to 2 cm. in diameter. The parotid duct comes in close relation with the sucking pad and may pass either directly above it or through a deep groove on its external surface. The sucking pad contains fats of a higher melting point than those of the general superficial adipose tissue and is little diminished even in cases of extreme emaciation. Its finer structure, in the newborn, is practically identical with that of the general superficial fat.


Calcification of the deciduous teeth.

Decalcification of the deciduous teeth.

Calcification of the permanent teeth.

FIG. 109.—Diagram illustrating the calcification of the permanent and deciduous teeth, and the decalcification of the latter. (After Poirier and Charpy, Traite Anat. Humaine, 2m. Éd.)

The body is surrounded by a special capsule of fibrous connective tissue. Its function is supposed to be the distribution of atmospheric pressure and preventing the drawing in of the cheek and buccinator muscle, between the gums during the sucking act (Ballantyne[1]). In most cases, the sucking pad persists throughout childhood and even into adult life.

THE TEETH (Figs. 92, 93, 107, 109, 110)

All of the deciduous teeth and the germs of the upper and lower permanent first molars are partially calcified at the time of birth. The germs of the remaining permanent teeth, with the exception of the third molars, are also present at this time although the process of calcification has not begun in them.

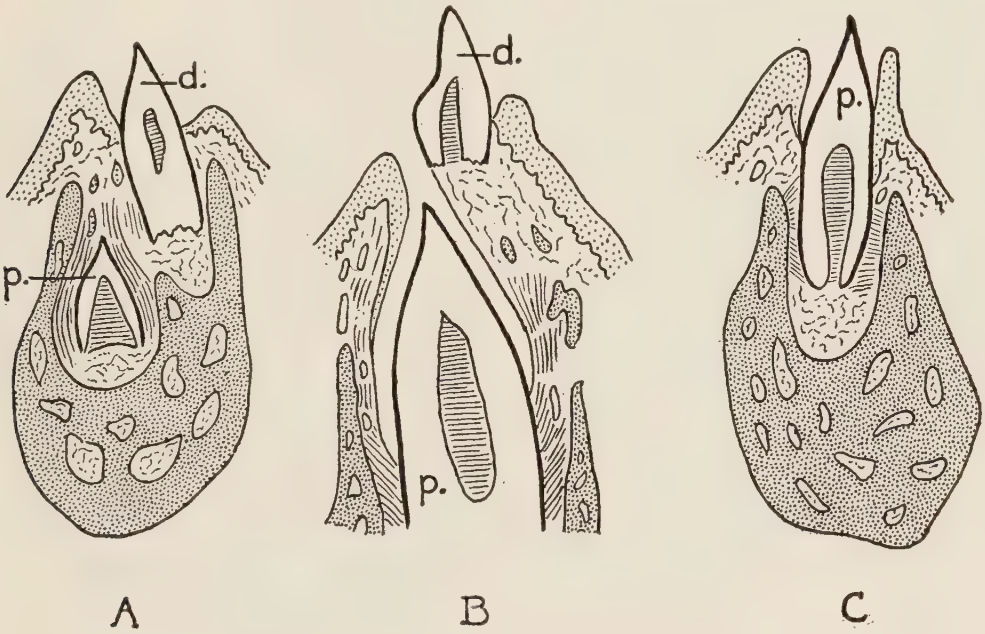


FIG. 110.—Semi-diagrammatic sections illustrating the shedding of the deciduous and eruption of the permanent teeth. A, child five and one-half years old, section through median inferior incisor. B, child six and one-half years old, section through lateral inferior incisor. C, child six and one-half years old, section through median inferior incisor. d., deciduous tooth; p., permanent tooth. (After Albarran.[64])

The germs of the deciduous teeth and of certain of the permanent ones are inclosed in definite connective tissue sacs (dental sacs) which are attached by their apices to the connective tissue of the oral mucous membrane and at their sides and bases to the periosteum of the mandible or maxillæ. These dental sacs are lodged in incomplete bony alveoli, which occupy the greater part of the mandible and of the bases of the maxillæ. The alveoli which contain the deciduous teeth extend from the bases of the rami of the mandibles to the symphysis in the lower jaw and from the posterior margins to the future nasal spines of the maxillæ. The germs of the anterior permanent teeth, from median incisors to the first premolars inclusive, lie medial to the deciduous teeth, while the germs of the first and second molars are placed posterior to them.

The chronology of the eruption of both the deciduous and permanent teeth is subject to great individual and probably some racial variation. Usually the eruption of the former begins with the lower central incisors in the early part of the second half year and ends with the second molars in the latter part of the second year. As a rule, the eruption of the deciduous teeth takes place in a series of periods of activity which are separated by periods of quiescence which grow progressively longer; but there is considerable variation in this process. The details of the calcification and eruption of the deciduous teeth are shown in Table 9 and Fig. 109.

Following the eruption of the second deciduous molars is a period in which there are no external changes in the dentation. During this time, however, all of the permanent teeth with the exception of the first and third molars commence to calcify and towards the end of it the decalcification of the deciduous incisors begins.

The shedding of the deciduous teeth, which is even more irregular than their eruption, starts with the incisors, usually in the seventh year, and ends with the premolars or second molars in the twelfth year.

The first of the permanent teeth to erupt are the first molars. These teeth undergo precocious development from the beginning, being the only ones of the permanent series which begin to calcify in fetal life. The usual time of eruption is in the sixth or seventh year. The permanent dentation, with the exception of the wisdom teeth or third molars, is usually complete by 14 or 15 years. The wisdom teeth may make their appearance at almost any time from this period to the close of the third decade, although generally they are erupted before 20. In general, the teeth of the permanent dentation appear from one to six months earlier in girls than in boys.

A few words may be added concerning the nature of these processes whose chronology has just been outlined.

The *calcification* of teeth begins at their crowns and proceeds towards the roots. Simple teeth, such as the incisors and canines, have single centers of calcification. Teeth with more than one cusp have separate calcification centers for each cusp. These centers fuse in their later development. In general, there are two main periods of calcification, one in the fourth and fifth fetal months, when the centers of the deciduous teeth are established; and a second extending through the first five years of post-natal life, when the centers of most of the permanent teeth are laid down. The exceptions to this scheme are the permanent first molars, which commence to calcify in the last fetal month; and the third molars or wisdom teeth, in which the process is delayed until the eight or ninth year. While clacification is always well advanced at the time of eruption it is not completed in the case of the deciduous teeth until some time thereafter. In the permanent teeth it is nearly or quite finished at the time of eruption.

The *decalcification* of the deciduous teeth begins at or near the apices of the roots and proceeds towards the crowns. When the tooth is shed practically all of the fang has been destroyed. This is said to be brought about mainly through the action of osteoclasts. Prior to the shedding of the tooth the upper part of the temporary alveolus is absorbed and the peridental membrane becomes loosened. A diagram of the process is shown in Fig. 110.

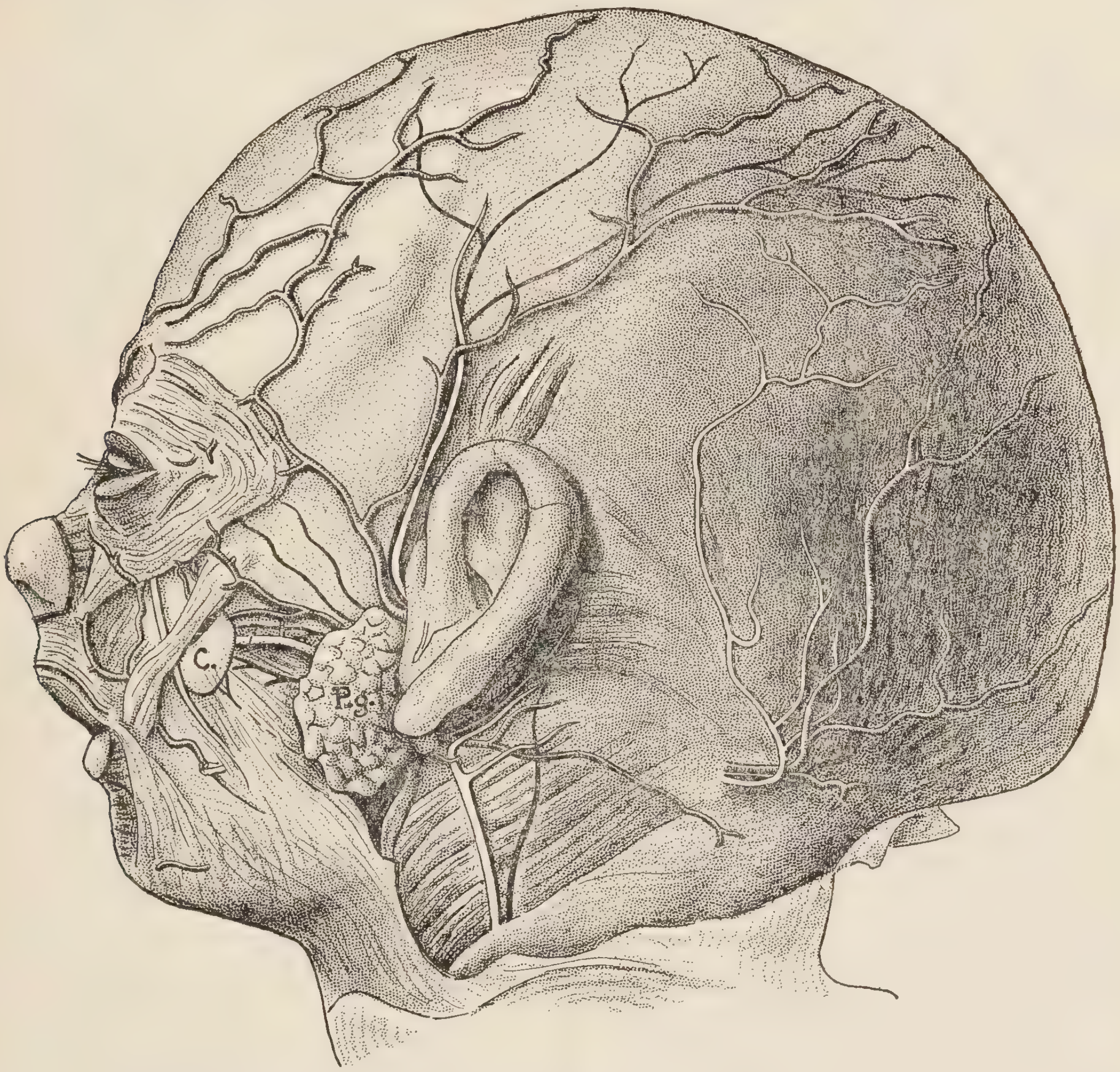


Fig. 111.—Dissection of the head of a child one month old. P.g., parotid gland; C., corpus adiposum buccæ (sucking pad).

In the process of *eruption*, the crown of the growing tooth is pressed against the oral margin of the alveolus which encloses it, and the aperture at this place is enlarged through the absorption of its margins until an opening is formed which is large enough to allow the passage of the crown. At the same time the mucoperiosteum covering this region becomes reduced in thickness and of softer texture. The crown pierces this tissue carrying a thin covering derived from the inner part of the enamel organ known as the dental cuticle or Nasmyths membrane. The remains of dental sac in which the tooth was enclosed fuses with and becomes part of the periosteum of the alveolus which is rapidly rebuilt around the neck of the tooth.

The details of the development of the teeth will be found presented in full in the texts of Noyes, and Broomell and Fischelis, and the

Table 9.—Summary of the Development of the Deciduous and Permanent Teeth
(Based on the observations of Broomell and Fischelis, and Röse)

Deciduous teeth

Upper and lower teeth	Calcification begins	Calcification completed	Usual time of eruption	Decalcification begins	Shedding begins
Medial incisors	4th fetal mo.	16th to 18th mo.	6th to 8th mo.	4th yr.	7th yr.
Lateral incisors	4th fetal mo.	10th to 16th mo.	7th to 9th mo.	5th yr.	8th yr.
Canines	5th fetal mo.	2 yrs.	17th to 18th mo.	9th yr.	10th yr.
First molars	5th fetal mo.	18th to 20th mo.	14th to 15th mo.	6th to 7th yr.	10th yr.
Second molars	5th fetal mo.	20th to 22nd mo.	18th to 24th mo.	7th to 8th yr.	11th to 12th yr.

Permanent teeth

Upper teeth	Calcification begins	Calcification completed	Average time of eruption		Usual period of eruption
			Males	Females	
Medial incisors	1st yr.	10th to 11th yr.	7 yrs. 8 mos.	7 yrs. 5 mos.	7th to 8th yr.
Lateral incisors	1st yr.	10th to 11th yr.	8 yrs. 11 mos.	8 yrs. 6 mos.	7th to 8th yr.
Canines	3rd yr.	12th to 13th yr.	12 yrs. 2 mos.	11 yrs. 7 mos.	12th to 13th yr.
First premolars	4th yr.	11th to 12th yr.	10 yrs. 5 mos.	10 yrs. 1 mo.	8th to 11th yr.
Second premolars	5th yr.	11th to 12th yr.	11 yrs. 4 mos.	11 yrs. 1 mo.	11th to 12th yr.
First molars	10th fetal mo.	9th to 10th yr.	6 yrs. 7 mos.	6 yrs. 6 mos.	6th to 7th yr.
Second molars	5th yr.	16th to 18th yr.	12 yrs. 9 mos.	12 yrs. 5 mos.	12th to 14th yr.
Third molars	9th yr.	18th to 20th yr.	....	....	17th to 20th yr.
Lower teeth					
Medial incisors	1 st yr.	10th yr.	6 yrs. 10 mos.	6 yrs. 7 mos.	7th to 8th yr.
Lateral incisors	1st yr.	10th to 11th yr.	7 yrs. 11 mos.	7 yrs. 7 mos.	8th to 9th yr.
Canines	3rd yr.	12th to 13th yr.	11 yrs. 2 mos.	10 yrs. 3 mos.	12th to 13th yr.
First premolars	4th yr.	11th to 12th yr.	11 yrs. 3 mos.	10 yrs. 8 mos.	10th to 11th yr.
Second premolars	4th to 5th yr.	11th to 12th yr.	12 yrs. 0 mos.	11 yrs. 7 mos.	11th to 12th yr.
First molars	10th fetal mo.	9th to 10th yr.	6 yrs. 5 mos.	6 yrs. 3 mos.	6th to 7th yr.
Second molars	5th yr.	16th to 17th yr.	12 yrs. 3 mos.	11 yrs. 9 mos.	12th to 16th yr.
Third molars	8th to 9th yr.	18th yr.	....	....	16th to 20th yr.

relations of the teeth in childhood are well illustrated in the atlases of Symington and Rankin[127] and Witzel.[139] Among the more extensive statistical studies upon the chronology of the eruption of the teeth are those of Röse[120] and James and Pitts.[97] The development and growth of the dental arches has been considered in connection with the post-natal history of the jaws.

THE SALIVARY GLANDS (Figs. 107, 111)

The relative weight of the salivary glands as a whole is approximately the same in the newborn and the adult. The parotid is however a little lighter proportionally while the submaxillary and the sublingual are a little heavier. The absolute weight of the parotid in the newborn averages 1.8 gm., that of the submaxillary 0.84 gm., and that of the sublingual 0.42 gm. All of these glands increase approximately three times in weight during the first six months, and five times during the first two years.

The topography of the submaxillary and sublingual glands is practically the same in the infant as in the adult and needs no special description.

The parotid gland in the newborn and young infant is rounder than in later life. It lies wedged in the hollow between the masseter muscle and the ear. During early childhood the parenchyma of the gland gradually grows over the surface of the masseter muscle along the course of the parotid duct until the final form of the adult gland is acquired.

The finer structure of the salivary glands in infancy is characterized by the relatively large amount of interstitial connective tissue and the limited amount of parenchyma. The lobules are separated by broad bands of delicate connective tissue in which the cellular elements are prominent. Within the lobules the ducts form a much larger proportion of the tissue than in later life. The basal granular rods of the secretory ducts are said to be absent during the first year. The end pieces are extremely variable in size as are the cells that form them. In the margins of the alveoli which lie at the periphery of the lobule there are found many small and undifferentiated cells evidently in the process of active growth. Mucous cells are found scattered among the smaller and more primitive ones. Small and faintly staining granules, which are probably secretory, are present in the end-pieces of the parotid and submaxillary gland at birth. According to Berger (quoted by Gundobin[7]) the salivary glands have acquired all the histological characters of the adult by the end of the second year.

THE PHARYNX (Figs. 108, 114, 133, 135, 139)

The pharynx in the newborn is about 4 cm. in length, being approximately one-third as long as in the adult. It is in contact superiorly with the basal portions of the sphenoid and occipital bones, and with the synchondrosis which joins them. The pharynx extends inferiorly to the level of the fifth or sixth cervical vertebra behind and the cricoid cartilage in front.

The main differences in form of the pharynx in the infant and the adult are found in the upper part of the structure. In the newborn, the nasal pharynx is a narrow tube about 20 mm. in length which runs anteroposteriorly in direct line with the nasal fossæ. Its transverse diameter is two or three times greater than the vertical. The nasal pharynx curves gently downward at its posterior end to join the oral pharynx, without any sharp line of demarkation.

During the first five years of life the form of the pharynx is greatly changed through the increase of its vertical diameter. In this period, according to the data of Escat,[84] the transverse diameter increases over one-half (from 12 to 15 mm. to 21 mm.), the anteroposterior diameter remains practical unchanged (at 20 mm.), and the vertical diameter increases nearly three fold (from 5 to 7 to 15 mm.). From 5 to 14 years all of the diameters of the pharynx increase but the vertical still grows the fastest. After puberty the growth of the nasopharynx takes place at about an equal rate in all directions. At birth and for some time thereafter no sharp line can be drawn between the posterior wall and the roof of the pharynx; the two form together a single curving surface. By five years, however, the posterior wall and roof meet at an oblique angle, and by puberty they join nearly at right angles, as in the adult.

The ostium of the Eustachian (auditory) tube at birth and during the first year lies at the level of the floor of the nasal cavity at the line of junction of the hard and soft palates. At this time the ostium of the tube is very small and the fold surrounding it (the torus tubarius) is practically absent because of the weak development of the tubal cartilage. After the first year the ostium is shifted upward and backward and by the end of the fifth or sixth year it generally lies posterior to the inferior nasal concha as in the adult. There is, however, considerable individual variation in the chronology of this process. The pharyngeal recess, or fossa of Rosenmüller, is often hardly distinguishable in the newborn. It is rendered prominent by the posterior shifting of the ostium and the coincident development of the torus tubarius.

THE PHARYNGEAL TONSIL (Figs. 114, 133, 135)

The posterior part of the roof of the pharynx contains a small median pit, the bursa pharyngea or fossa of Luschka, and from this pit a series of folds radiate forward and laterally. The pharyngeal tonsil is formed by the infiltration of these folds with lymphoid cells during the latter part of fetal life. At birth sections of this region show a pseudostratified epithelium, resting on a broad band of connective tissue containing ill defined masses of lymphoid tissue and numerous small mucous glands. During the first year the lymphoid tissue is greatly increased, and definite follicles with germinal centers are formed.

The pharyngeal tonsil reaches its maximum development in the sixth year according to the observations of Symington.[126] When at its greatest development it may be 30 mm. long and 15 mm. broad and may, in normal cases, project half-way across the cavity of the nasal pharynx. Involution of the pharyngeal tonsil, according to Symington, begins at six or seven years and is completed before puberty but occasionally the organ may persist to maturity. The bursa pharyngea commonly persists throughout adult life, often in the form of a small closed cyst.

The Palatine Tonsils (Figs. 112, 113)

At the time of birth the palatine tonsils have generally lost their simple fetal form and show many of the variations in shape and relation to the surrounding structures which are seen in the adult. Only the most common form of the tonsil is described below. For detailed descriptions of the numerous variations the reader is referred to the papers of Mosher[153] and Grünwald.[90]

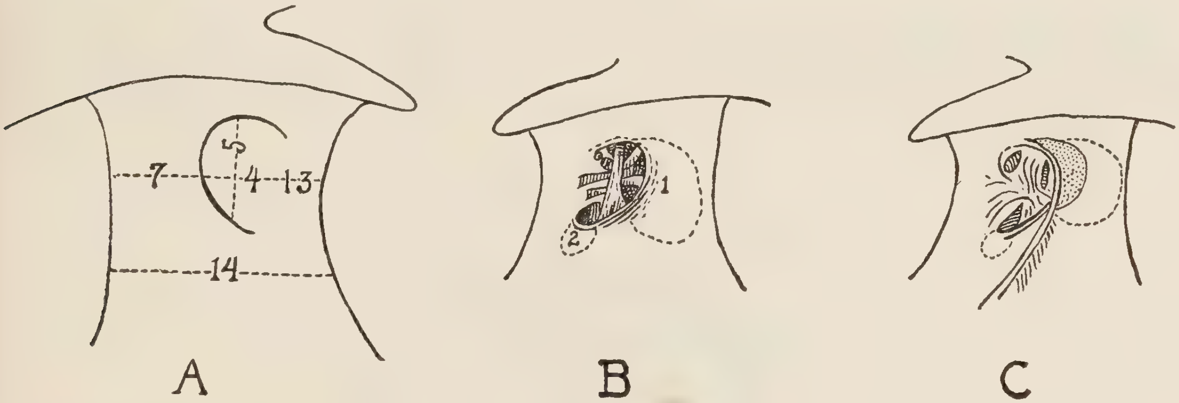


Fig. 112.—Drawing illustrating the position and form of the tonsil in the newborn. A., medial view of the right tonsillar region, average dimensions of different parts indicated in mm. B. and C., lateral views of tonsils at birth showing the position and extent of the commoner peritonsillar fossæ.

At birth, as in later life, the tonsil is lodged in the tonsillar sinus between the two palatine arches and the lateral margin of the tongue. The tonsillar sinus is relatively short and broad in the infant and a fold of mucous membrane, the plica triangularis, is reflected from the anterior palatine arch across the upper part of the tonsil. The plica triangularis ends in a free edge which ordinarily forms about three-fourths of a circle around the tonsillar mass, bounding it except for a small portion of its posterior border. As a rule, the upper third of the tonsil is covered by the plica triangularis in the newborn (Mosher). A number of fossæ may be found between the plica triangularis, the tonsil, and the floor of the tonsillar sinus. In the infant the commonest fossæ are an anterior and superior one, corresponding in part to the supra-tonsillar fossæ of the adult, and a smaller inferior one which projects downward from the posterior-inferior quadrant of the tonsil.

The tonsil as a whole lies higher in the tonsillar sinus than in the adult and its axis is horizontal instead of vertical as in the latter. It is placed more medially, *i.e.*, closer to the soft palate than in later life. The tonsil descends somewhat in infancy and its axis changes from the horizontal to the vertical position in the first two or three years of life.

Lymphoid tissue is found underlying the tonsillar epithelium in the sixth fetal month but definite lymphoid nodules are not formed until about the time of birth, and often germinal centers do not appear until the end of the first post-natal month. The tonsillar epithelium is invaded by lymphocytes before birth but according to Goslar,[89] they are not found in the cavities of the tonsillar crypts until a week or so after birth. Plasma cells also are not found in the tonsils until several days after birth (Davis[77]).

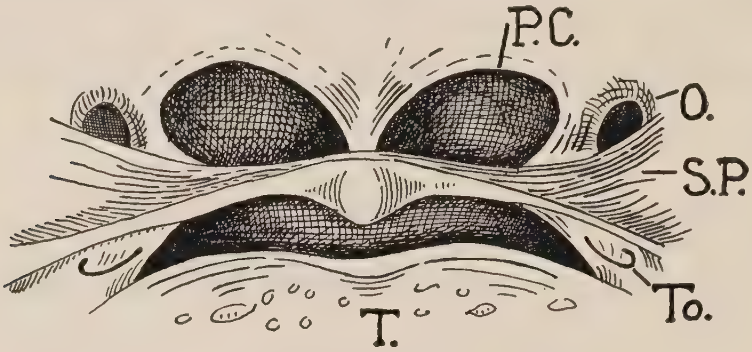


Fig. 113.—Soft palate and surrounding structures of the newborn as seen in posterior view. O., ostium of auditory tube; P.C., posterior choanæ; S.P., soft palate; T., tongue; To., tonsil. (After Mosher.[113])

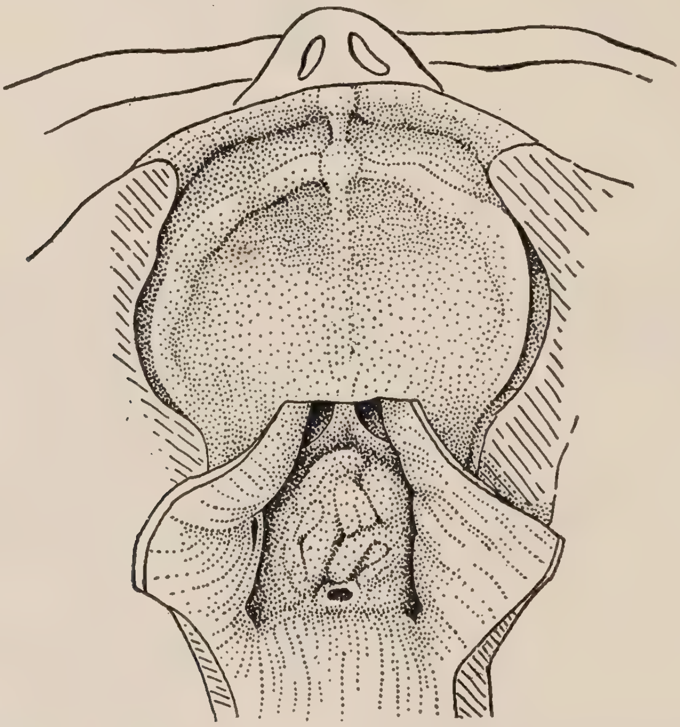


Fig. 114.—Dissection of the mouth and pharynx of a male child one month old, showing the hard palate, the pharyngeal tonsil and the pharyngeal bursa. (Considerably modified from Schwabsch, Arch. f. mikr. Anat., Bd.[29])

The changes which the tonsils undergo in the latter part of childhood are still little known. Genter (quoted by Gundobin[7]) found the weight of the tonsil in the newborn to be 0.75 gms. It increases rapidly to 0.4 gms. in the second year and to 0.8 gms. in the fifth year. In the second decade the average weight is slightly over 1 gm., and in the third and fourth decades nearly 1.5 gms. No decrease in weight was observed until the fifth decade. These figures however are based on weighings of the entire tonsil including its surrounding and interstitial connective tissue. They give us no indication of the amount of lymphoid tissue present in the structure at different ages. Hett and Butterfield[94] conclude from the study of a large series of sections of the tonsils of children that the tonsil normally begins to atrophy at or soon after five years. The majority of observers would set a later date for the beginning of involution in these structures.

THE ESOPHAGUS

The esophagus in the newborn varies in length from 8 to 10 cm., measuring from the cricoid cartilage to the cardia. This length doubles during the first three years of life. Thereafter the increase is slow, the adult of length 23 to 30 cm., being attained some time after puberty. In the newborn and young infant the esophagus is slightly more than one-fourth of the combined length of the head and trunk while in the adult it is equal to about one-sixth or one-seventh of the length of the head and trunk. The length of the esophagus from the incisor teeth, which is of more practical importance, is given in the table of Stark quoted below.

TABLE 10.—THE LENGTH OF THE ESOPHAGUS IN CHILDHOOD (AFTER STARK)

Age	Total length centimeters	Distance, in centimeters, from incisor teeth (or margin of gum) to the level of		
		Cricoid cartilage	Bifurcation of trachea	Cardia
Birth	10	7	12	18
1 yr.	12	10	14	22
2 yrs.	13	10	15	23
5 yrs.	16	10	17	26
10 yrs.	18	10	18	28
15 yrs.	19	14	23	33
Adult	25	15	26	40

At birth the average diameter of the esophagus, as measured with the sound, is 5 mm. The caliber of the esophagus in childhood has been measured by means of sounds by Lesbini[106] and by Schkarin (quoted by Gundobin[7]). The former found the maximum diameter in children from two to five years to be 15 mm., from 12 to 16 years 20 mm., and over 16 years 21 mm. The latter found the diameter in children under two months to be from 7 to 8 mm., between six and nine months 9 mm., between nine months and two years 10 mm., and from 6 to 12 years 12 mm. The wide divergence in these two sets of measurements probably represents only the great natural variation of the esophagus in this respect.

In the newborn the superior limit of the esophagus lies at the level of the fourth or fifth cervical vertebra, and the inferior margin at the ninth thoracic vertebra. Thus both the upper and lower end of the tube lie from one to two vertebræ higher than in the adult. The curvatures of the esophagus, while present in the infant, are less pronounced than in the adult. The same statement holds true for the normal esophageal constrictions.

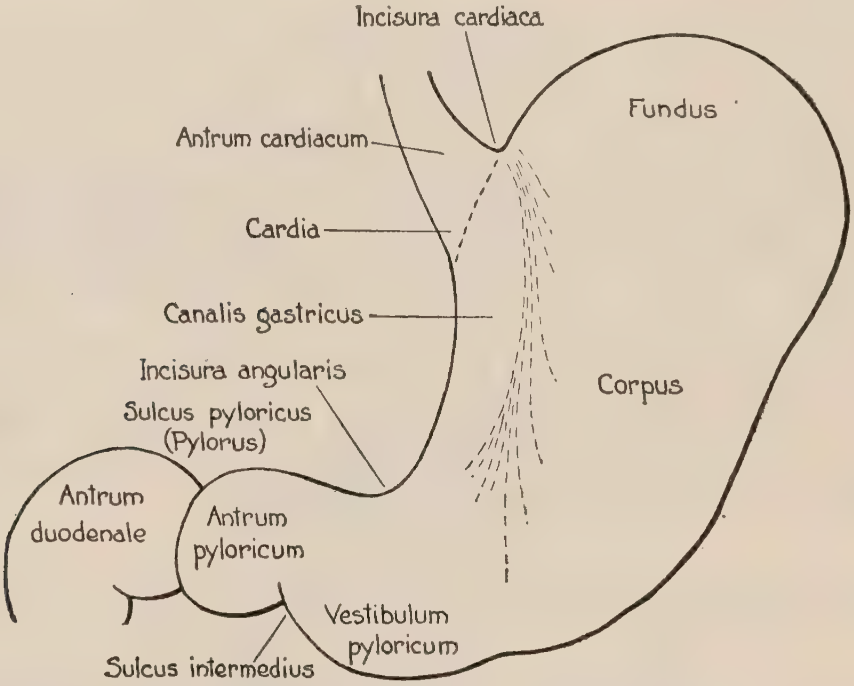


Fig. 115.—Diagram illustrating the divisions of the stomach. (After Lewis.[108])

The esophagus at birth is lined with a stratified squamous epithelium which is distinctly thinner than that of the adult and which may present small scattered areas covered by a superficial layer of columnar ciliated cells. The epithelium rapidly thickens after birth and the ciliated areas, when present, disappear. Both the deep and the superficial esophageal glands are present at the time of birth. The former are less numerous than in later life and their end-pieces are only in the process of formation. The muscularis mucosa is relatively thick in the infant.

THE STOMACH (Figs. 115, to 124, 127, to 130, 147, 156)

Our conceptions of the form of the stomach have been greatly modified in recent years by studies of material hardened in situ and still more through the evidence furnished by the Roentgen ray method. Indeed some investigators would go so far as to say that no definite form can be assigned to the organ because of its varying form in relation to gastric contents and to the waves of contraction which pass along it. This is hardly true, for Lewis' study on the development of the stomach shows conclusively that all of the subdivisions which have been demonstrated in the adult, by strictly anatomical methods of investigation and by the Roentgen-ray, are present in the fetal organ, long before it is influenced by gastric contents or, so far as we know, by physiologic waves of contraction. As much of the

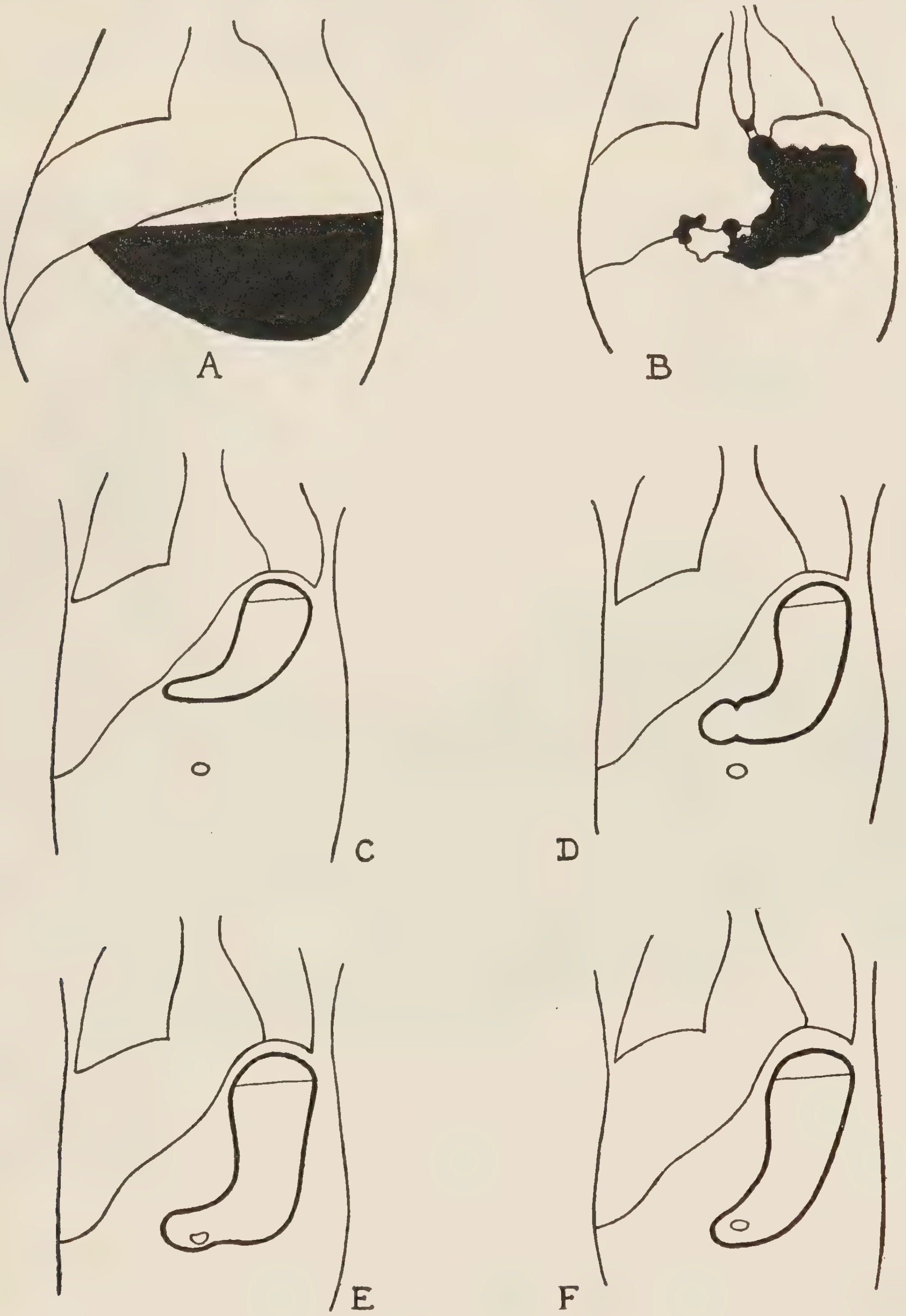


Fig. 116.—A series of outline tracings of radiographs of the stomach in childhood. A, child of five months. B, child of three months. C, child of eight months. D, girl of seven years. E, boy of nine years. F, girl of 12 years. All radiographs taken with the stomach moderately distended and the subject in the erect position. (A and B after Major, 110. C–F, after Flesch and Péteri.[87])

confusion regarding the form of the stomach is due to conflicting nomenclature I adopt for the following description that proposed by Lewis[108] which is illustrated by Fig. 115. All of the divisions of the organ shown in this figure are usually recognizable in the newborn if one examines material which has been properly hardened in situ or fresh specimens which are moderately contracted (Figs. 117, 147). The divisions of the pyloric portion are usually particularly clear and the sulci bounding them well marked.

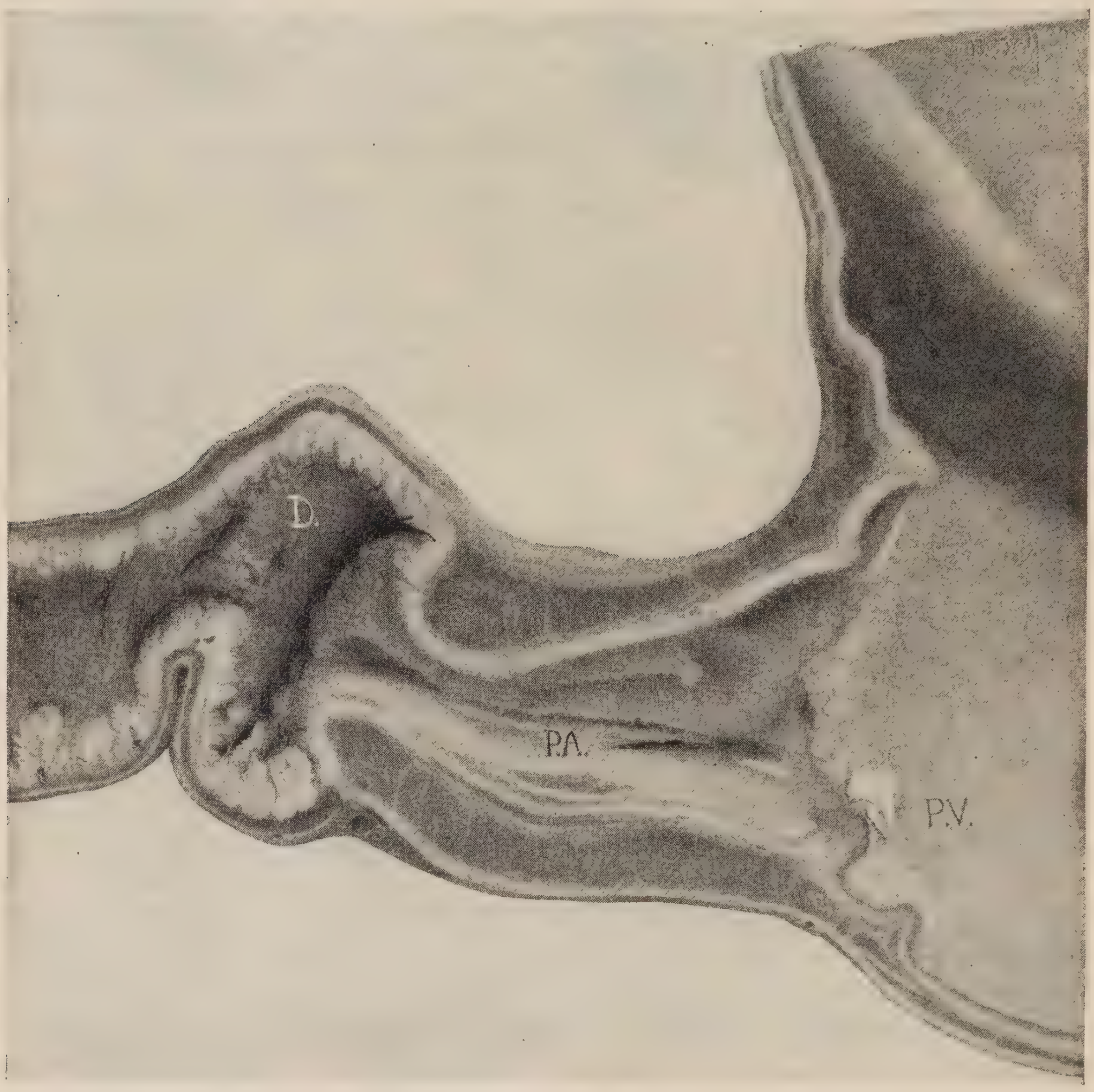


Fig. 117.—A longitudinal section of the pyloric end of the stomach and the duodenum of a full-term child one day old. D., duodenum; P.A., pyloric antrum; P.V., pyloric vestibule (pyloric canal). Twice natural size.

The older anatomical accounts of the form and position of the infant's stomach and the results found by radiographic studies are radically opposed. Almost all anatomists describe the stomach of the newborn and infant as placed vertically with the greater curvature to the left and the lesser to the right. They also generally include the statement that the infant's stomach lacks a fundus. On the other hand radiographs of the suckling's stomach, taken with the subject in the erect position, practically always show the stomach lying transversely in the body with the greater curvature forming its lower margin and with a distinct fundus which extends upward some distance above the cardia and is occupied by a gas bubble. The form, then, of the slightly or moderately distended infant's stomach as seen in *x*-ray has been aptly described as that of an inverted retort. The discrepancy in these two classes of descriptions is due, I think, to the fact that anatomists have generally examined stomachs either in a high degree of contraction or those of premature infants or fetuses which have never been even moderately distended. In still-born children the widest variation in the amount of gastric contents is found. The walls of the sac may be almost in contact or the organ may contain 20 c.c. or more of mucus. In almost all cases of the latter type which I have observed, the long axis of the stomach was either oblique or transverse. At birth the gastric contents is greatly increased, at first by the introduction of air, which begins with the first inspiration, and later with fluid. If the transverse position of the stomach has not previously been established by the accumulation of gastric mucus it is brought about at this time by the factors I have just mentioned. The change in the direction of the stomach's axis is due not to the actual shifting of the viscus as a whole but to the expansion of the lower part of the corpus and particularly of that portion which lies to the left. The fundus is well established long before birth but it also shares somewhat in the expansion of the left part of the corpus following the increase in gastric contents.

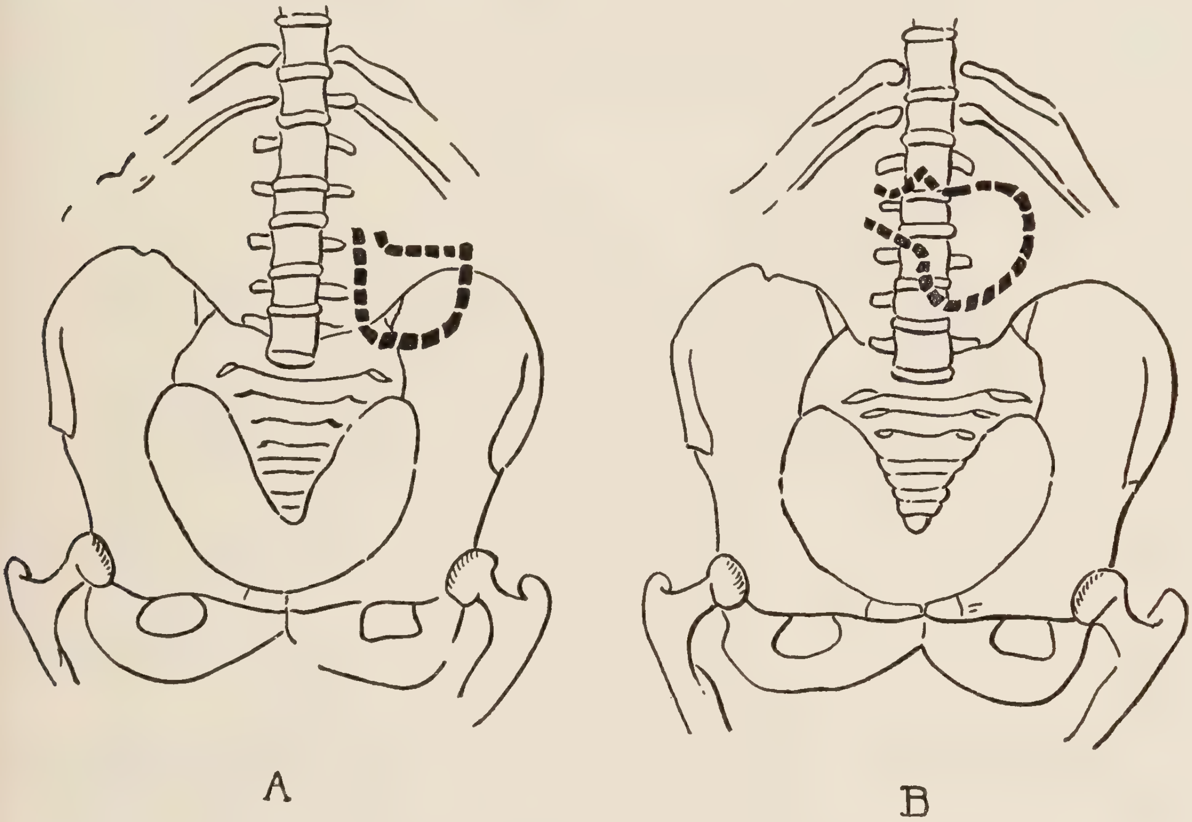


Fig. 118.—Outline tracings of radiographs showing the position of the stomach in relation to the skeleton in later childhood. (After Sever.[123])

According to radiographic studies, the transverse position of the moderately filled stomach is only characteristic of early infancy. In the second or third year the "cows-horn" form described by Holzknecht for the adult, and somewhat later the "fish-hook" or "sink-drain" form described by Rieder, become the more common types. In other words, the stomach tends to return to the vertical position seen in the fetus. Possibly this change is brought about in part by the effect of gravity as the child begins to assume habitually the erect posture, and in part by the growth of the lesser pelvis which permits a portion of the small intestines to pass into the pelvic cavity and thus leaves more space for the stomach to sag downward in the abdominal cavity.

With these changes in form and direction of the axis of the stomach the position is also modified. While the stomach retains its transverse position its lowest point, which is in the greater curvature, rarely lies below the umbilicus even when the viscus is well distended. With the development of the "cows horn" form the pyloris generally lies at the umbilicus or a little below it. Later, with the development of the "fish-hook" form, there is still a greater descent and Sever[123] found that in a large series of children averaging 10 to 11 years old who were apparently normal, the lowest point of the stomach varied from the fourth lumbar vertebra to a point well below the iliac crests. This position is lower than that ordinarily found in the adult and if this author's observations are correct there must be some ascent of the stomach between puberty and maturity.

Gastric Capacity.—The capacity of the stomach in infancy has been tested by a large variety of methods. These may be divided into two classes, the physiologic and the anatomic. The physiologic method of weighing the child before and after feeding is, on the whole, distinctly the more accurate, since it allows the selection of any number of cases of which the condition and antecedents can be accurately known; and also because single cases may be studied over a considerable period of time. The disadvantages of this method are the inability to determine accurately the degree of distension of the stomach, without recourse to the *x*-ray, and the possibility of over estimation of the weight of the gastric contents through the inclusion of the weight of milk which is retained in the esophagus or which has passed into the duodenum.

These possibilities of error are negligible in comparison to the great advantages of the method. The anatomic method consists of introducing into the stomach of the cadaver some substance which can be easily measured and then determining the amount required to fill the organ. Many modifications of this method have been employed, chiefly with an eye to securing a "normal" expansion of the stomach.

Thus Holt[95] distended the viscus until the rugæ disappeared, Muggia[115] and Pfaundler[118] filled it at varying degrees of water pressure and Mosenthal[112] introduced water into the stomach in situ until the organ filled its place in the abdominal cavity. Perhaps the simplest and best anatomic method is that of Zuccarelli[140] who removed the stomach from the body, distended it with water, and then plunging the organ into a vessel of water opened its orifices. As soon as the pressures of the water within and without the organ had adjusted themselves the openings of the organ were again clamped, the organ removed and its content measured by pouring it into a graduated vessel. Anatomic methods of measuring gastric capacity have the grave disadvantage of being applicable only to material which is often pathologic and of giving results which are dependent in a considerable measure on the degree of contraction of the stomach at the time of death. It is only when a large series of measurements of this type are available that the results are of much value, and then their worth is only a relative one.

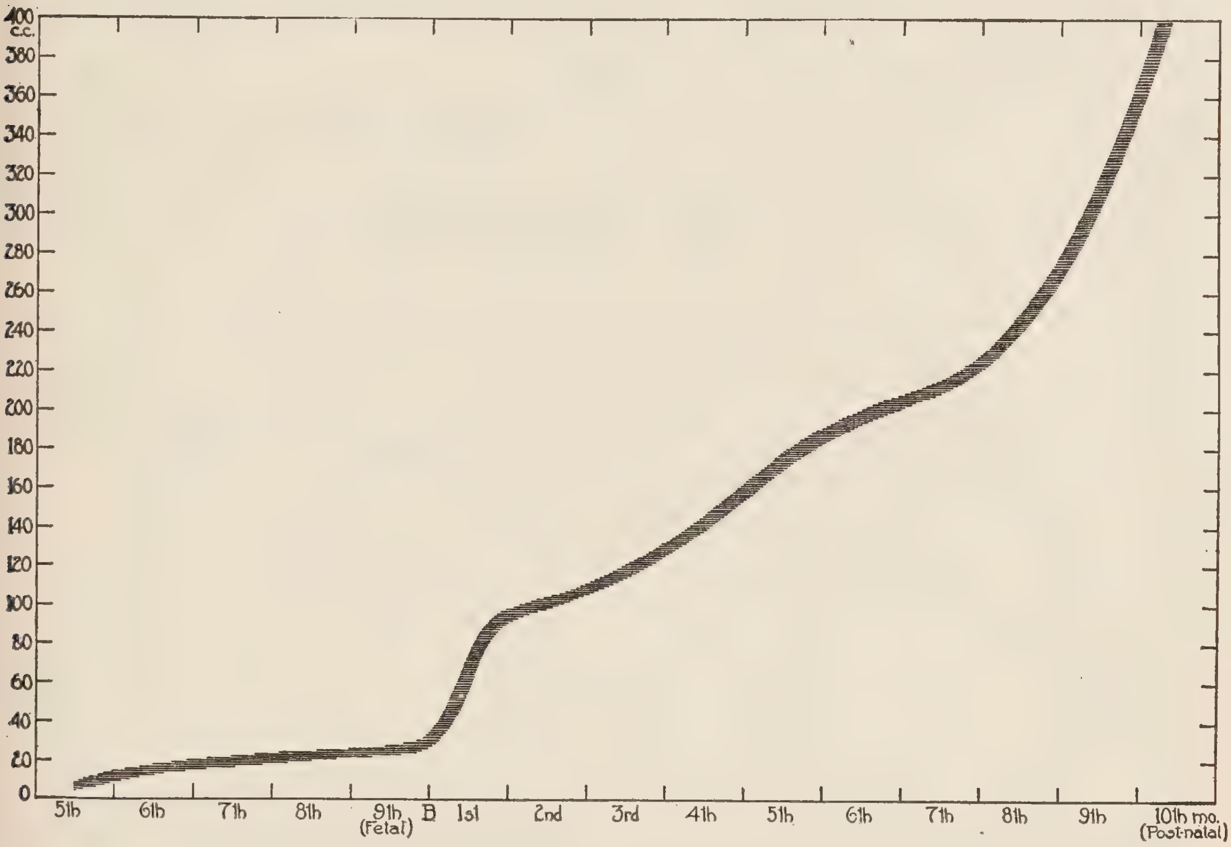


Fig. 119.—A semi-diagrammatic graph illustrating the increase in gastric capacity in c.c., as determined by anatomic methods, from the fifth fetal month to the end of the first year. (Based upon the data of Alliot, Borie, Dargien, Muggia, Zuccarelli and others; and on material collected by the writer. Total ca. 200 cases.)

The chief advantage of the anatomic method is that it is possible to investigate the gastric capacities of fetuses and of older children, which cannot be studied by the physiologic method.

The average anatomic capacity of the stomach, as determined by Zuccarrelli's method, is about 10 c.c. in the fifth fetal month. It rises rapidly to about 20 c.c. by the middle of the sixth fetal month but thereafter the increase to the close of prenatal life is rather slow. In the full-term newborn the average anatomic capacity lies between 30 and 35 c.c. This rises to about 45 c.c. in the middle of the first week, and to about 75 c.c. in the second week. At the end of the first month of post-natal life the average capacity, as determined by all anatomic methods, is about 100 c.c., or nearly three times that of the child at birth. Following the first month there is a period of slow increase in anatomic capacity which extends nearly to the end of the third trimester. During this period the actual capacity is slightly more than doubled, and the rate of increase is about 30 per cent. per month or about one-tenth that observed in the first four weeks of extrauterine life. At the eighth month the curve of anatomic capacity rises rapidly probably through the increase of a number of diastolic stomachs in the material of this age available for study.

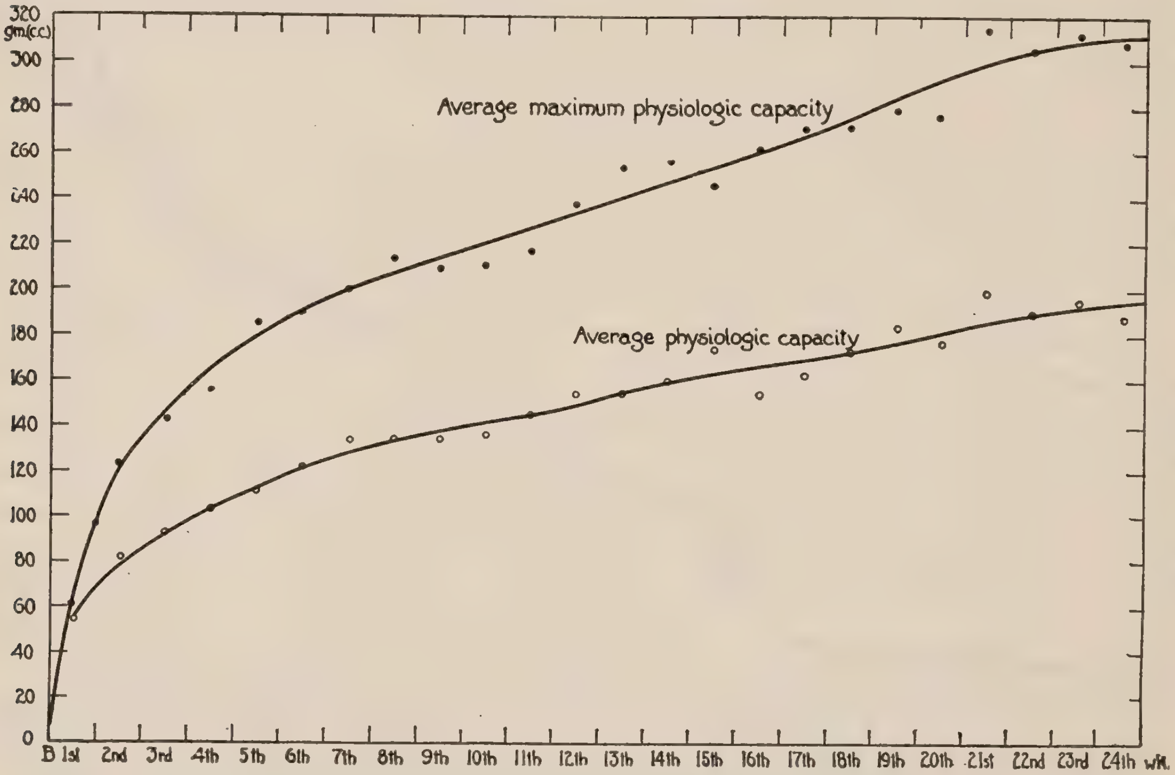


FIG. 120.—Graphs illustrating the changes in physiologic gastric capacity as shown by the feeding records of 11 full-term children most of whom were entirely breast-fed.

The data upon the anatomic capacity in later childhood are less extensive than those regarding the growth in the first year. Probably the average capacity in the second year is not far from 500 c.c., about 550 c.c. in the third year, and in the fourth year about 600 c.c. In the latter half of childhood the average gastric capacity probably lies between 750 and 950 c.c.

The average physiologic capacity of the stomach in the first day after birth is about 7 gm. This rises very rapidly to about 45 gm. on the fourth day when it becomes equal to the anatomic capacity. In the second week the average capacity is about 90 gm. Thereafter until the end of the first year the average physiologic capacity increases at a fairly regular rate of about 20 or 25 c.c. per month. Curves of the average physiologic capacity and the average anatomic capacity run parallel from about the fourth day after birth until nearly the end of the third trimester but the physiologic capacity is generally a little greater than the anatomic capacity as determined by the usual methods.

Curves of the maximum physiologic capacity in the suckling, as determined by averaging the largest meal taken in a given week, are found to agree closely in type with those of average physiologic capacity although the values are at all times from 25 to 50 per cent. greater in the former. Figure 120 shows curves of the average and the average maximum capacity in the first year as determined by the physiologic method.

The increase in the surface area of the gastric mucous membrane during childhood is difficult to determine with any accuracy as it is of course dependent upon the degree of extension of the stomach. The table of Dargien,[75] which is given below, is the most extensive piece of work on the subject. As will be noted from the table, the gastric capacities of the several cases agree fairly well with those determined by other authors and the areas are therefore fairly accurate.

TABLE 11.—THE AREA OF THE GASTRIC MUCOUS MEMBRANE IN CHILDHOOD (AFTER DARGIEN[75])

Age	Length of the greater curvature, centimeters	Gastric capacity, cubic-centimeters	Gastric surface area, square centimeters
Newborn (1)	9.5	32	12.0
Newborn (2)	11.0	36	13.5
Child 2 mos	13.0	95	31.0
Child 3½ mos	16.0	120	48.0
Child 5 mos	17.0	140	55.0
Child 6½ mos	19.0	145	67.0
Child 8 mos	19.0	215	82.0
Child 11 mos	21.0	240	118.0

The Finer Structure of the Stomach.—The mucous membrane of the stomach in the newborn and in early infancy is relatively much thicker than in older children and in the adult. The lining gastric epithelium is composed of a single layer of high columnar epithelium, which is continued into the crypts of the gastric glands. The cells lining these crypts are actively secreting mucus at the time of birth. The true gastric glands are shorter and broader and branch more freely than in the adult. According to the estimates of Toldt,[128] about seven gastric glands open into a single crypt in the newborn. Parietal or acid cells are present although they are not fully differentiated at birth. Fischl[85] found them fully developed by the end of the second year. The total number of gastric glands at birth is estimated by Toldt[128] as almost 2,000,000 as compared with nearly 17,000,000 at 10 years, about 22,500,000 at 15 years, and over 25,000,000 in the adult. As these estimates are based in part upon measurements of the area of the gastric mucous membrane, and as this area is in turn dependent upon the degree of expansion of the stomach the value of these figures is only relative; but there is, without doubt, a tremendous increase in the number of gastric glands during childhood, and a still greater increase in the number of gastric crypts. The post-natal development of the cardiac and pyloric glands has not been investigated in detail. Both Fischl and Toldt state that

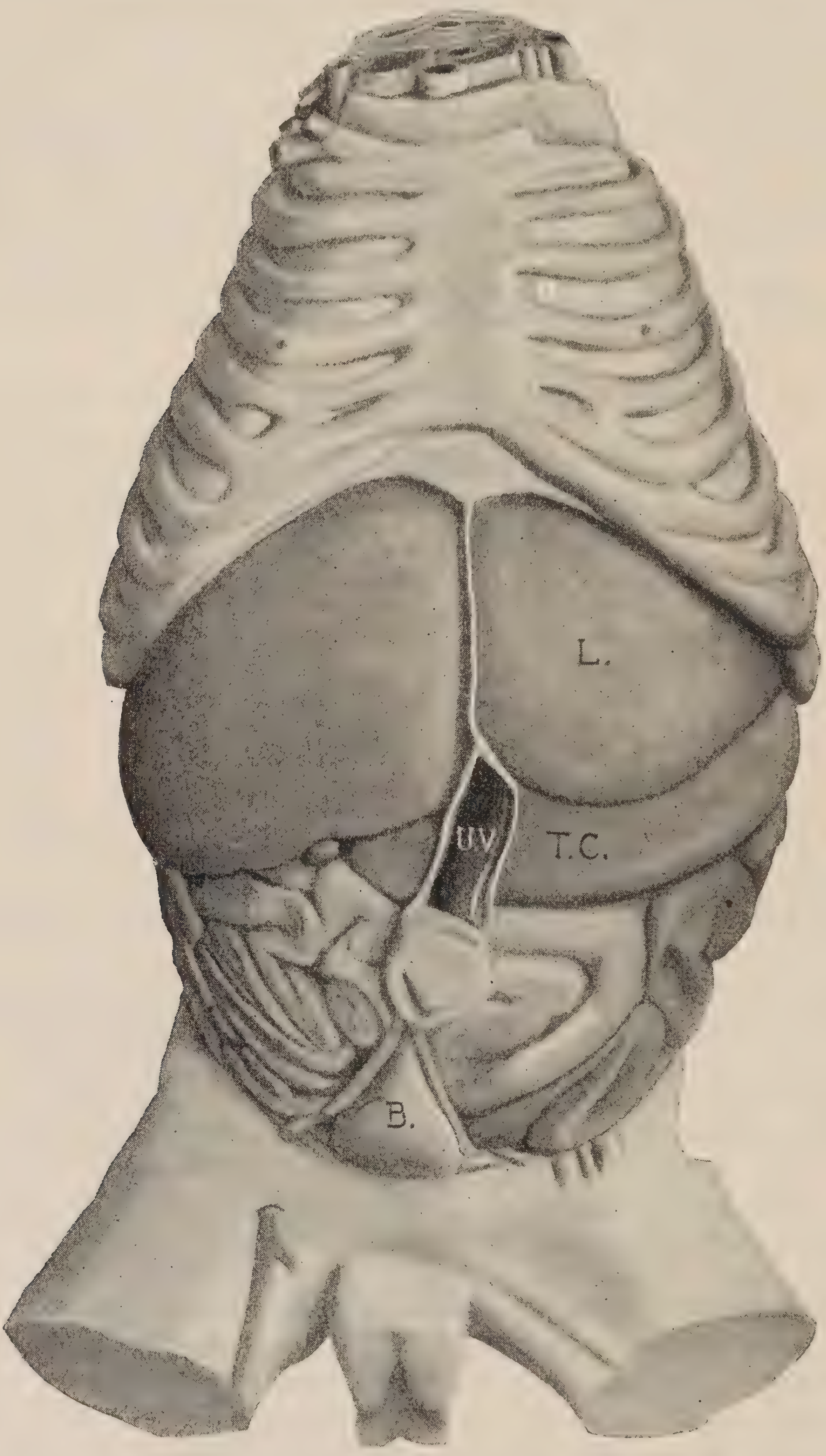


Fig. 121.—Anterior view of a cast of a dissection of the trunk of a full-term, newborn female child. (Drawn from a preparation made by Dr. L. W. Barry.) B., bladder; L., liver; T.C., transverse colon; U.V., umbilical vein. Three-fourths natural size.

parietal cells are not found in the pyloric glands of children but Johnson[98] found them in a fetus of 24 cm.

The musculature of the stomach, aside from that of the pyloric canal and sphincter, is only moderately developed at the time of birth. The longitudinal layer being incomplete over a part of the greater curvature. According to Fishel both layers of the muscularis mucosa are present at this time. The elastic tissue is very poorly developed and is confined mainly to the walls of the arteries.

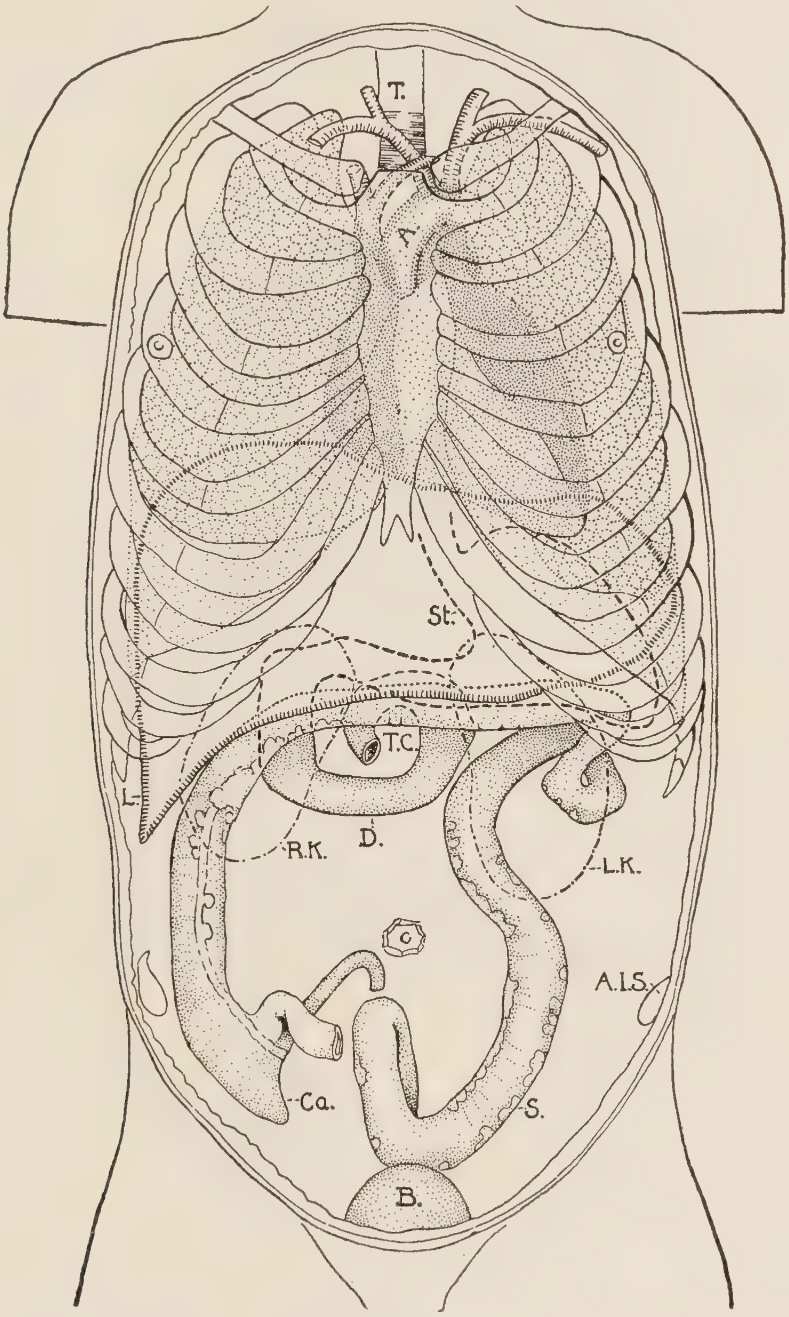


Fig. 122.—A graphic reconstruction, from transverse sections, of the thoracic and abdominal viscera of a boy about five years old. A., arch of aorta; A.I.S., anterior superior iliac spine; B., bladder; Ca., cecum; D., duodenum; L., liver; L.K., left kidney; R.K., right kidney; S., sigmoid colon; St., stomach; T., trachea; T.C., transverse colon. (After Symington.[14])

Lymph-nodules have been observed in stomachs of the newborn but their number is both absolutely and relatively less in childhood than in maturity.

THE INTESTINAL TRACT

The Intestinal Tract as a Whole.—The weight of the intestines, emptied of their contents, is about 10 gm. in the seventh fetal month. During the last two months of fetal life the weight of the intestinal mass increases at a very rapid rate so that the average weight in the full-term newborn is nearly 50 gm. There are no accurate figures, so far as I am aware, on the weight of the intestines in normal children.*

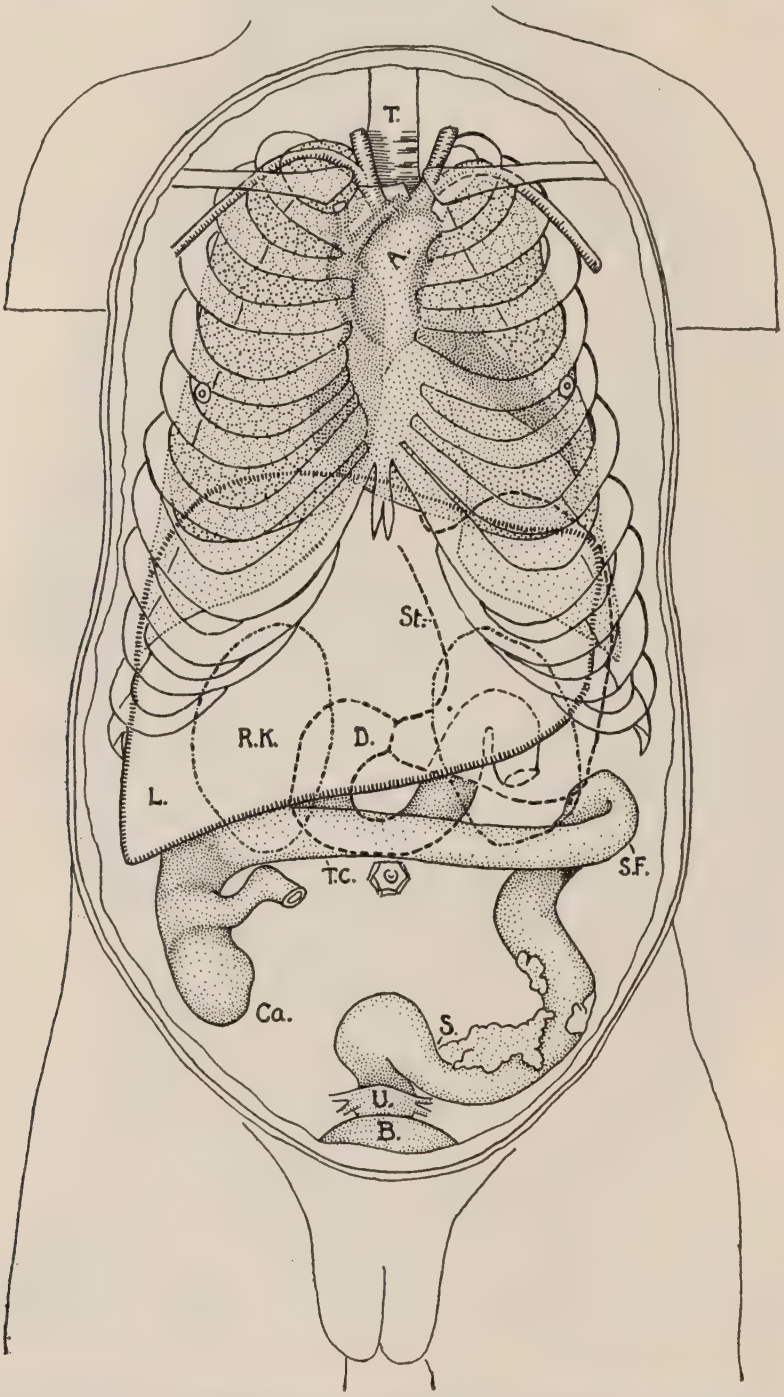


FIG. 123.—A graphic reconstruction, from transverse sections, of the thoracic and abdominal viscera of a girl about five years old. A., aortic arch; B., bladder; Ca., cecum; D., duodenum; L., liver; R.K., right kidney; S., sigmoid colon; S.F., splenic flexure; St., stomach; T., trachea; T.C., transverse colon; U., uterus. (After Symington.[14])

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* A small series of weighings of the intestines of children has been published by Muhlmann. But Muhlmann's figures on the weight of the intestines in the newborn and adult are so different from those of other observers that the value of the whole series can probably be questioned.

In the adult Messedaglia and Vainanidis found the average absolute weight to be approximately 490 gm., nearly 10 times greater than that of the child at birth. The relative weight of the intestinal mass decreases from about 1.5 per cent. in the infant to about 0.75 per cent. in the adult.

The length of the intestines at birth is quite variable and this variation does not seem to be intimately associated with that of body length or weight. In 25 full-term newborn children I find the average length of the total intestinal tract, from pyloris to anal canal, to be 338.5 cm. In this series the maximum length was 461 cm. and the minimum 336 cm. This average is somewhat greater than found by most observers, probably because all premature children were ruled out. The intestinal tract increases about one-third in length during the first year of life. Thereafter the growth is much slower. The absolute length of the intestines in the adult is approximately twice that of the newborn. The ratio of the length of the intestine to the length of the entire body is much greater in the infant than in the adult. The ratio in my series of newborn children was as 8.3 : 1 and in Messedaglia's and Vainanidis' series of adults as 5.4 : 1. Beneke[68] found the ratio in the adult to be still lower (4.5:1). This change in the relative length of the intestine is not due so much to the reduced rate of lineal growth of the intestine as to the rapid growth of the lower extremities for if the length of the intestine is compared with that of the trunk less change is observed. Thus Debele[78] found this relation in children of the first month to be 1:16.6, in those of the entire first year 1:18.5 and in those between 9 and 10 years 1:15.9. Fehling similarly found little difference between the intestine-trunk ratio in the newborn and the adult. The ratio between the length of the large intestine and small intestine remains almost unchanged throughout post-natal life.

Passow's[117] data show that the surface area of the intestinal tract increases approximately fourfold between infancy and maturity. This result is based on gross measurements of the inner surface area of the canal. The actual increase in intestinal epithelial area is actually somewhat less, as there is a relative decrease in the number of intestinal folds and villi after birth.

Further details of the dimension and growth of the intestines will be found in the following table and in the paragraphs dealing with the several segments of the intestinal tract.

The shape of the intestinal mass in the newborn and infant is quite different from that of the adult. On opening the abdomen in the infant the intestines present an oval anterior surface bounded above by the liver and left costal margin, and below by the brim of the pelvis. Owing to the great relative breadth of the abdomen and the large size of the lever, the greatest diameter of the anterior surface of the intestinal mass is transverse in the infant whereas it is vertical in the adult. The mass is indented in the anterior median line by a wedge shaped depression which is occupied by the large abdominal portion of the bladder. In medial sagittal section, the intestinal mass appears as an acute scaline triangle with its base formed by the anterior abdominal wall, its shorter side by the inferior surfaces of the stomach, spleen, and liver; and its longer posterior side by the psoas and iliacus muscles, the spine and the iliac crests, and the kidneys and suprarenals. In the newborn the intestines are almost equally divided between the right and left sides of the abdominal cavity. The rectum usually is the only part of the intestines which lies in the pelvic cavity at birth. It is not until after infancy that any considerable part of the small intestines descends into the lesser pelvis.

The Finer Structure of the Intestinal Tract.—The most striking characteristic of the infant's intestine, as seen in section, is the comparatively weak development of the muscular layers. In the child at birth and for sometime thereafter the mucosa, submucosa and muscularis are of equal thickness. In the adult the muscularis is as thick as the mucosa and submucosa combined. The longitudinal layer of muscle is particularly thin in the newborn. These observations hold good for the entire intestinal tract.

In the newborn the villi are distributed the entire length of the small intestine as in the adult. The villi increase rapidly in number during the later part of fetal life according to the observations of Johnson. Hilton has estimated the number in the newborn at 1,000,000 whereas the number present in the adult intestine is generally estimated at from 4,000,000 to 6,000,000. Nothing is known of the rate of increase in post-natal life or when this increase ceases.

The intestinal glands or crypts of Lieberkuhn are but half as long although almost as thick in the newborn as the adult. Their number increases greatly during childhood. This is probably brought about mainly by the longitudinal division of existing glands, and not by the evagination of the surface epithelium of the intestine. At the time of birth many glands are apparently in the process of division being bifurcated at their bases. Goblet cells are quite as numerous in the intestinal glands of children as of adults.

The post-natal development of the duodenal glands or glands of Brunner has never been studied in detail. They are said to be smaller and less branched in the newborn than in the adult.

Lymphoid tissue is present both in the large and small intestine at the time of birth. As a rule, it is in the form of diffuse masses without definite germinal centers. There is a marked increase in the amount of lymphoid tissue during the first year, and germinal centers generally make their appearance within a few weeks after birth. Passow[117] found the relative number of both solitary and aggregated lymph-nodules (Peyer's patches) greater in children than in adults. The existence of lymph-nodules in the appendix at birth has been denied by some investigators but they are certainly present at this time as is shown by the studies of Sudsuki[125] and Johnson[99] and by the reconstructions of Hines, one of which is reproduced in Fig. 125.[31] There is, no doubt, some increase in the number of nodules in the appendix during the first year as in other parts of the intestinal tract.

The elastic tissue of the intestine of the newborn is confined almost entirely to the walls of the blood vessels. It increases greatly during the first few months of post-natal life.

The distension of the large intestine by meconium in the latter part of fetal life has a marked effect upon the structure of its walls. All of the layers are reduced in thickness, the intestinal glands become much shorter and broader and the intervals separating them are increased. The villi, which are present in the large intestine during the greater part of fetal life, are also shortened, broadened and separated. These changes are described in detail by Johnson.[99]

The Small Intestine (Figs. 121, 122, 123, 132, 147, 151, 155).—The small intestine is from 300 to 350 cm. in length in the full-term newborn child (average of 25 cases 338. 5 cm.). Its length increases about 50 per cent. in the first year of life and is approximately doubled by puberty. Great individual variations in the length of the small intestine are encountered in children.

The arrangement of the intestines in the newborn has been studied by Mall[111] on hardened material. He found the attachment of the mesentery to be along a curved line extending from the left hypochondriac region to the right iliac fossa. The intestines were arranged in coils along this line crossing and recrossing it. The convolutions lying above and to the left of the mesentery were arranged in coils with their planes at right angles to the body while those lying below and to the left were arranged with their planes perpendicular to the body (Fig. 121).

The duodenum is from 7.5 to 10 cm. long at birth. The annular type of duodenum is the commonest in the newborn and suckling although the U-shaped type is seen occasionally. The superior end of the duodenum in the newborn lies at the level of the first lumbar vertebra, or the intervertebral disc below it. The inferior end lies at the same level or a little lower. The loop of the duodenum extends from 1 to 1.5 cm. to the right of the median line and is often directed downward so that the lowest point on the loop may lie no more than a centimeter above the right iliac crest. The inferior end of the duodenum is often lodged in the notch in the lower border of the stomach between the pyloric vestibule and the pyloric antrum. Figures 132, 147 show the form and relations of the duodenum in the late fetus and newborn.

The Large Intestine (Figs. 121, 122, 123, 124, 125, 126, 127, 129, 132, 147, 151, 153, 155).—The cecum in the infant is much smaller relatively as well as absolutely than in the adult. Charpy, in a series of newborn children, found the average capacity to be 2.5 c.c., the average length 15 mm. and the average breadth 17 mm. Thus, as in the adult, the cecum of the newborn is broader than it is long. At birth the cecum almost always presents a smooth external surface. Two main types can be recognized: First, the "dropped cone" type in which the cecum tapers gradually into the vermiform process which

TABLE 12.—THE LENGTH OF THE INTESTINE
(Based on the Data of Brandt, Arnoljevic, Debele, Weinberg, Valtorta, Messedaglia and Vainaindio, and Scammon)

Age	Number of cases	Length of large intestine in centimeters	Length of small intestine in centimeters	Length of total intestine in centimeters	Relation of length of large intestine to length of small intestine	Relation of body-length to intestine-length	Relation of trunk-length to intestine-length
8th fetal month	7	46.4	249.1	278.5	1:5.3	1:7.3	
9th fetal month	9	62.5	283.7	340.8	1:4.5	1:8.3	
10th fetal month	15	64.5	301.5	366.0	1:4.6	1:8.1	
Birth	25	66.0	338.5	402.6	1:5.1	1:7.9	
1 to 3 months	25	67.9	337.4	405.3	1:4.9	.....	1:18.7
3 to 6 months	15	70.7	380.9	451.6	1:5.3	.....	1:18.0
6 to 12 months	9	83.1	418.1	501.2	1:5.0	.....	1:18.5
1 to 2 years	6	88.9	460.4	549.3	1:5.1	.....	1:17.2
2 to 4 years	6	88.1	468.6	556.8	1:5.3	.....	1:17.3
4 to 6 years	10	99.9	469.9	569.8	1:4.7	.....	1:14.4
6 to 8 years	7	108.5	500.6	609.1	1:4.6	.....	1:14.3
8 to 10 years	7	116.4	579.0	695.4	1:4.0	.....	1:15.9
Adult	14	160.7	753.9	914.6	1:4.6	1:5.3	

lies directly below it; and second, the "b-type" in which the lower extremity of the cecum together with the vermiform process, is bent upward at an acute angle with the upper part of the sac. The "b-type" is much the commoner of the two. No sharp line of demarkation can be recognized between the cecum and vermiform process in the majority of infant specimens; the cecum tapers into the process through an ill-defined conical termination which Parsons[116] has termed the conus appendicis.

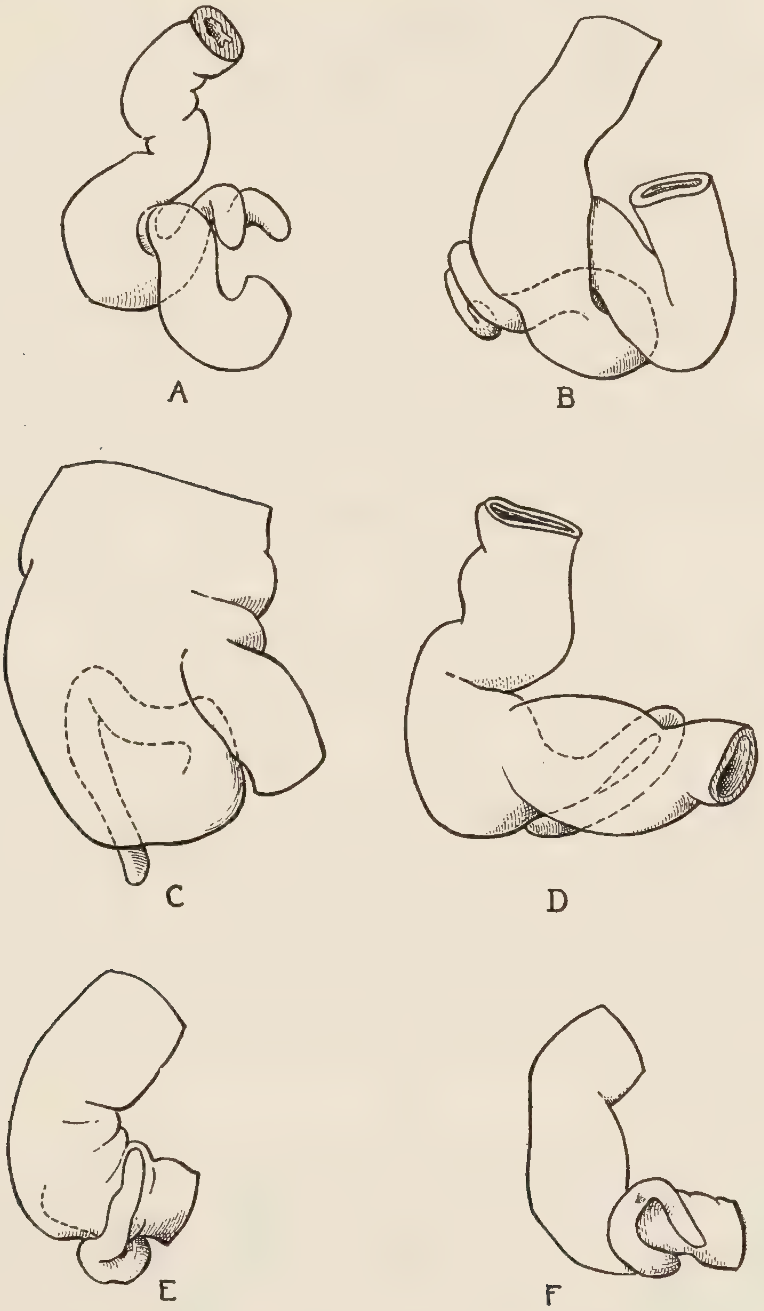

FIG. 124.—Six examples of the cecum and appendix of the newborn. These specimens were taken at random from the autopsy room and have not been selected to show unusual variation. All natural size.

The taenia of the cecum are present but ill-defined at the time of birth. The haustra are absent in the newborn if the intestine is distended with meconium but appear in the first six months of postnatal life. With the development of the haustra the sacculations of the cecum make their appearance but it is not until the third or fourth year that the typical sacculated cecum of the adult is fully differentiated.

Toldt[129] has pointed out that the ilio-cecal valves are produced by the bending of the cecum and vermiform process upon the colon. This process takes place in early fetal life so that the leaves the valves are well established before birth. They increase greatly in length in the later fetal and the early post-natal months.

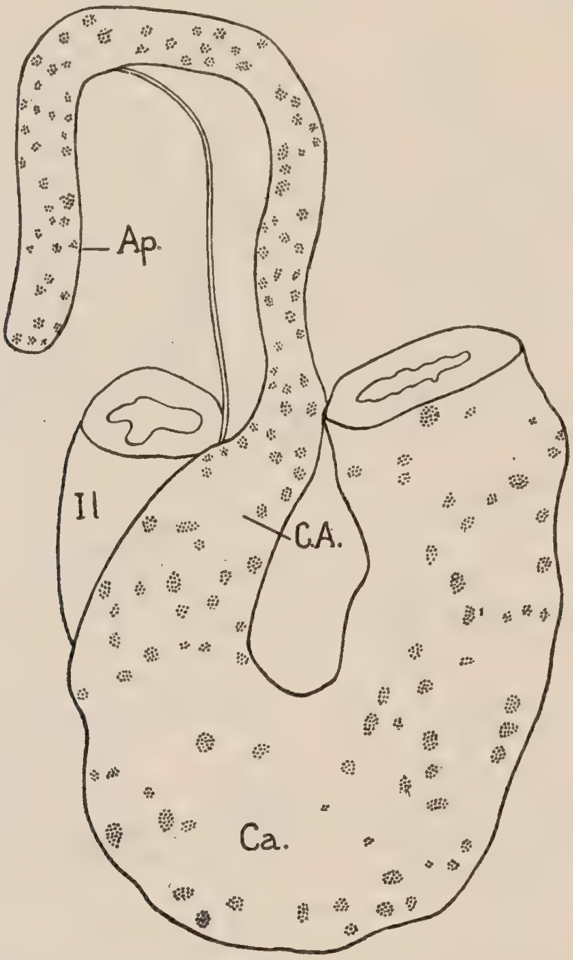

Fig. 125.—A graphic reconstruction, from transverse sections, of the cecum and appendix of a full-term, still-born child showing the number, form and distribution of the lymphoid masses which are indicated in stipple. Ap., appendix; Ca., cecum; C.A., conus appendicis; Il., ileum. Twice natural size. (Reconstruction by Dr. Charles Hymes.)

Contrary to the common opinion often expressed in text-books, the position of the cecum in infancy and childhood and is not more elevated than in the adult. This is strikingly shown in the table of findings of Legueu[105] which is given below. The observations of other investigators, including my own, confirm those of Legueu. Vallée[131] found the cecum below the right anterior superior iliac spine in nearly three-fourths of the hundred infants which he examined. Smith,[271] in a series of over 1000 autopsies on infants, found the cecum undescended in about 6 per cent., in the right iliac fossa in about 85 per cent., and in the pelvis in nearly 10 per cent.

The axis of the cecum is usually either vertical or else ascending and directed a little to the right. The posterior surface of the cecum in infancy is generally in contact with the lower part of the right kidney, the crest of the ilium, and the upper part of the ilio-psoas muscle. The anterior surface is covered by coils of the small intestine and often by a loop of the sigmoid flexure of the colon.

TABLE 13.—THE POSITION OF THE CECUM IN INFANCY (AFTER LEGUEU[105])

Age	Sex	Number of cases	Position of cecum					
			Lumbar		Iliac		Pelvic	
			Number	Per cent.	Number	Per cent.	Number	Per cent.
Birth to three years	m.	32	2	6	25	78	5	16
	f.	18	1	6	10	56	7	39
	Both	50	3	6	35	70	12	24
Adult.....	m.	100	3	3	82	82	15	15
	f.	100	1	1	62	62	37	37
	Both	200	4	2	144	72	526	26

The appendix or vermiform process of the newborn varies in length from 2 to 8 cm. Extraordinary cases having a length of 10 cm. or more have been reported. The statement, occasionally made, that in relation to the large intestine the appendix is relatively longer in

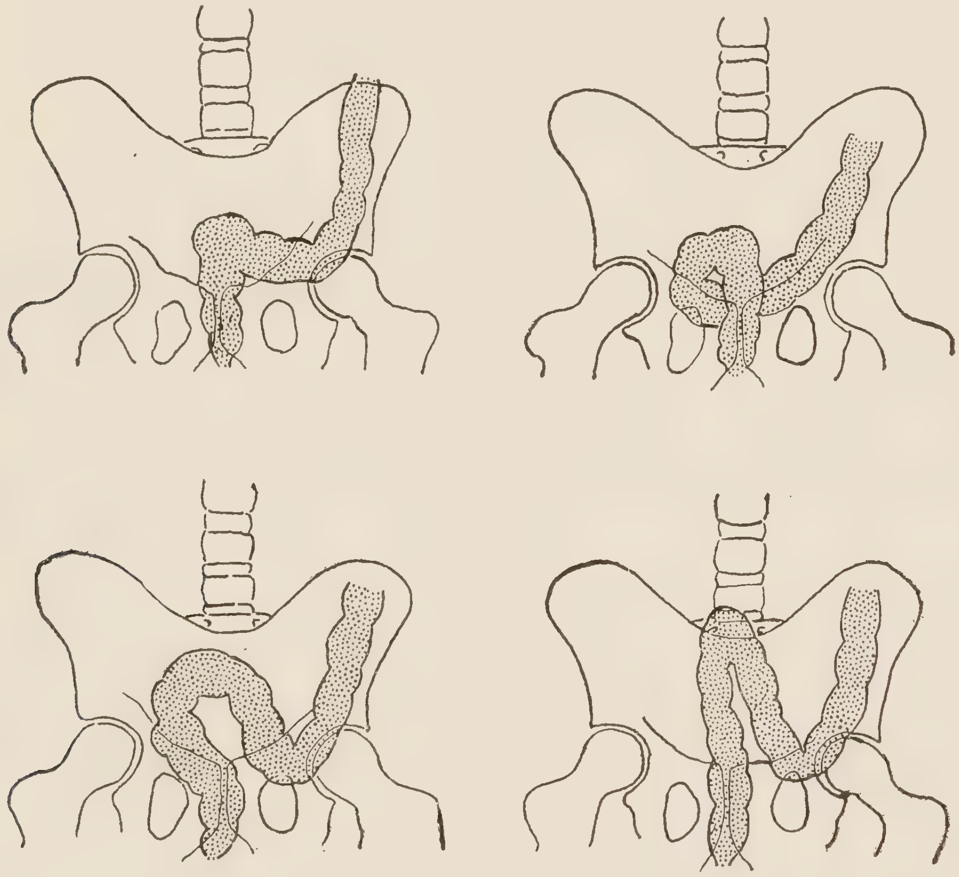

FIG. 126.—Four radiographs showing the form and position of the rectum and sigmoid colon in infancy. (After Peteri, Jahrb. f. Kinderheilk., Bd. 82.)

the infant than in the adult is not verified by the data I have examined. The diameter of the appendix at birth varies from 2 to 6 mm. The appendix increases in length quite rapidly during the first year of life attaining an average length of from 8 to 10 cm.; thereafter its growth is very slow and irregular.

As stated in the section on the cecum, the appendix is generally connected with the cecum by an enlarged and rather indefinite basal segment, the conus appendicis.

The direction of the appendix in the suckling is as variable as in the adult. In a hundred infants examined by Vallée it was found to be horizontal in 32 per cent., oblique in 10 per cent., vertical-ascending in 34 per cent., and vertical-descending in 24 per cent.

In some hundred and fifty cases collected by Liertz,[109] Vallée,[131] and the writer, the appendix lay medial to the cecum in one-half, retrocecal in one-third and free below in over one-tenth of the instances. The remainder were irregular in position but in only two cases in the series, one a premature, was the appendix lateral to the cecum. Vallée found the appendix lying above the anterior superior iliac spine in 72 per cent., below the spine in 22 per cent. and in the true pelvis in 6 per cent. of his hundred cases.

The opening from the appendix to the cecum may be guarded by a crescent-fold of mucous membrane known as the valve of Gerlach (Valvula processus vermiformis *BNA*). Sudsuki[125] found this structure present in over half of the appendices of children of 10 years or younger which he examined; and present in slightly less than one-fourth of the adults.

The ascending colon is relatively as well as absolutely shorter in the newborn and suckling than in the adult. This is due not to the position of the cecum, which is at least as low as in maturity, but to the small dimensions of the lumbar region. The ascending colon may either pass directly upward or, more commonly, upward and to the left. Posteriorly, the ascending colon is in contact with the left kidney and the lower part of the right suprarenal. The anterior relations vary considerably: Sometimes the entire ascending colon lies under the cover of the left lobe of the liver, but usually a few coils of the small intestine come in contact with the lower part of its inferior surface.

Because of the frequent obliquity of the ascending colon the left colic or hepatic flexure is often poorly marked.

The transverse colon is relatively long in the young infant. It may pass straight across the abdomen, form a gentle curve with its convexity directed downward, or be thrown into a series of short abrupt curves. In the newborn the transverse colon may lie entirely under the cover of the liver but ordinarily it projects below the margin of the left lobe from a point a centimeter or so to the left of the median line. The greater part of this projecting portion comes in direct contact with the anterior abdominal wall, for the greater omentum is not developed sufficiently at this time to fully cover it (Fig. 121).

The transverse colon is in contact with the duodenum, with the head of the pancreas, often with the anterior surface of the kidney posteriorly, and with the stomach and first part of the duodenum superiorly.

The splenic, or right colic, flexure is well marked in infants. According to the observations of Fleury,[320] it generally reaches the level of the ninth or tenth rib, while in adults its apex usually lies at the level of the seventh or eighth rib. Contrary to the usual description of the splenic flexure, I find that the colon is almost always in contact with the spleen at birth and that its impression forms a considerable area on the medial side of that viscus.

The descending colon is comparatively short. It is in contact with the left kidney and the quadratus lumborum.

The sigmoid colon is the most striking part of the large intestine in the newborn. It is generally enormously distended with meconium and, as the lesser pelvic cavity is too small to contain any considerable part of it, it projects far upward into the abdomen. The sigmoid colon may take a variety of forms for which several classifications have been suggested. Following that proposed by Bourcart,[70] three main types can be recognized—the ascendant, the transverse, and the descendant. The ascendant type is by far the commonest—being found in 80 per cent. of all cases by Bourcart and 75 per cent. by Gysi.[91] In this type three intestinal loops are formed. The first is small with its apex directed downward, and lies in the left iliac fossa. It passes over into the main loop which is directed upward into the abdominal cavity and which may reach the level of the umbilicus or even higher. The descending limb of the main loop joins the small third loop which passes into the lesser pelvis. In the second type, the main loop of the sigmoid passes transversely across the lower part of the abdomen and its apex is lodged in the right iliac fossa. Twenty to 25 per cent. of sigmoid flexures are of this variety. In the third type, which is quite unusual, the sigmoid passes directly over the left iliac fossa into the lesser pelvis. The main loop of the sigmoid colon is almost always in front of the small intestines and in contact with the anterior intestinal wall. In one-half of all cases a part of the sigmoid colon lies in the right iliac fossa.

The rectum is relatively longer at birth and in early life than in the adult. While the lower part of the tube descends vertically and is straighter in infancy than in later life, the upper portion is usually directed to one side of the pelvis, more commonly to the right. The pars analis recti lies completely below the level of the tip of the coccyx at birth, (Johnson[100]), and the anal opening is somewhat posterior to its adult position. The rectal sinuses and columns, and the transverse rectal folds are all differentiated sometime before birth, although the latter may be temporally obliterated in the newborn by the distension of the upper part of the rectum by meconium. In the infant, the peritoneum extends downward in front of the rectum to the level of the fourth sacral vertebra (Ballantyne[1]).

THE PANCREAS (Figs. 132, 147, 151, 156)

Until the sixth month of fetal life the pancreas is extremely small both relatively and absolutely. In the sixth month, however, histologic evidences of secretion appear in the gland and with these there is a marked increase in the rate of the growth. In the newborn the pancreas weighs from 2.0 to 2.5 gm. and forms about 0.07 per cent. of the total body-weight. During the first two months of post-natal life the gland apparently increases little in mass; but between three and six months its weight is doubled, and by the end of the first year it weighs about 10 gm. The relative as well as the absolute weight of the pancreas increases during the first year. Between one and three years the gland is again doubled in weight but after the third year its growth is much slower. The weight of the pancreas in the adult is over 30 times that of the newborn.

Microscopic sections of the pancreas at birth show the alveoli arranged in compact masses which are separated by wide connective tissue septa. The alveoli are fewer in number in each lobule, and are smaller individually than in later life; and the smaller ducts are more in proportion to the amount of parenchyma. Secretory granules can be demonstrated in the alveolar cells after the sixth fetal month. The finer vascular supply is noticeably richer in the newborn and in the first few months of life than later.

The relative number of islets of Langerhans is greater in the newborn than in later life. The extensive micrometric studies of Wilms[138] showed a reduction of four-fifths in the relative number of islets per square millimeter of both the head and tail of the pancreas between three months and four years. Clark,[73] whose technique is much superior since he used modern intra vitam staining methods immediately after death, also found a slightly greater relative number of islets in the infant than in the adult. The actual total number of islets is apparently greatly increased. Clark estimated that the number in a child of six months to be 120,323 while the average number similarly estimated for six adults was over 800,000. The reported smaller size of the islets in infancy is open to doubt since they have not been measured after preparation by modern methods. In infancy, islets are found in the interlobular connective tissue and at the peripheries of the lobules as well as within them. The islet cells are smaller and less distinct than later. Their connective-tissue support and capsule is also less developed. Most of the distinguishing microscopic characteristics of the newborn's pancreas disappear during the first year of life.

The pancreas is from 4 to 6 cm. in length and from 1 to 2 cm. in thickness in the newborn. As in the adult, the subdivisions of head, body, and tail can be distinguished although there is no sharp line of demarkation between the last two portions. The head forms a somewhat greater part of the gland in the newborn than in the adult. The surface markings are less pronounced at birth than later, particularly the tuber omentalis which is generally only a small papilla. At this time the pancreas lies at the level of the second or third lumbar vertebræ. The head is enclosed in the loop of the duodenum and comes in relation with the aorta and vena cava behind, and the transverse colon anteriorly. The body is directed to the left and generally upward as well. The tail is either continued upward and to the left in line with the body or, less commonly, is bent downward at a blunt angle to it. The tail and body are triangular in cross-section having superior, inferior, and posterior surfaces. The superior surface is in contact with the stomach and, near the head, with the papillary process of the liver. To the left the posterior surface comes in contact with the left suprarenal or left kidney, generally the former, and with the spleen. The slight changes in the position and relations of the pancreas in later childhood have not been investigated.

Distension of the stomach causes a flattening and widening of the superior and posterior surfaces of the pancreas with a reduction of its inferior surface. Distension of both the stomach and intestines flattens the organ anteroposteriorly and causes a considerable diminution in the area of its posterior surface. In the second instance, the viscus is projected forward, shelf-like, and increases the area of the bed of the stomach; in the first, it is flattened against the posterior abdominal wall (Jackson[96]).

THE LIVER (Figs. 121, 122, 123, 127, 128, 129, 130, 131, 132, 151, 163)

The liver of the full-term newborn child generally weighs between 120 and 150 gm. The average weight in a series of over 100 cases collected by the writer from the literature and from personal observation was 135 gm. All cases of known or suspected lues congenita were omitted from this series. The weight of the liver is more than doubled in the first year and tripled in the third. By the ninth year the liver has increased six times and by puberty nearly 10 times. The total increase in the weight of the liver between birth and maturity is about twelve- or thirteen-fold. The organ forms about 4 per cent. of the body weight at birth, 3 to 4 per cent. during the greater part of childhood and 2.5 to 3 per cent. in the adult. As the liver is, one of the most variable organs in weight in the body, the statements given above are to be regarded as approximations only; and specimens which are apparently normal may be far above or below the given averages.

There are a number of records of the dimensions of the liver in childhood, but most of these are of little value because they are based upon measurements of the fresh specimens removed from the body. Ruge,[21] who studied a few specimens which had been properly hardened in situ, found that the average height was about 8 cm., the average breadth about 11 cm., and the average thickness about 7.5 cm. Thus the height and breadth are about one-half the adult dimensions and the thickness about two-thirds. Although I have made no series of measurements on the newborn I am inclined to think that Ruge's measurements will be found distinctly above the average if an extensive series of specimens is examined.

According to Ruge's studies, the breadth of the liver in the newborn is to its thickness as 1.4 or 1.47 : 1 while in the adult this relation varies from 1.3 : 1 to 1.8 : 1. The relation of breadth to height was as about 1.4 : 1 in the newborn and 0.95 : 1 to 1.2 : 1 in the adult.

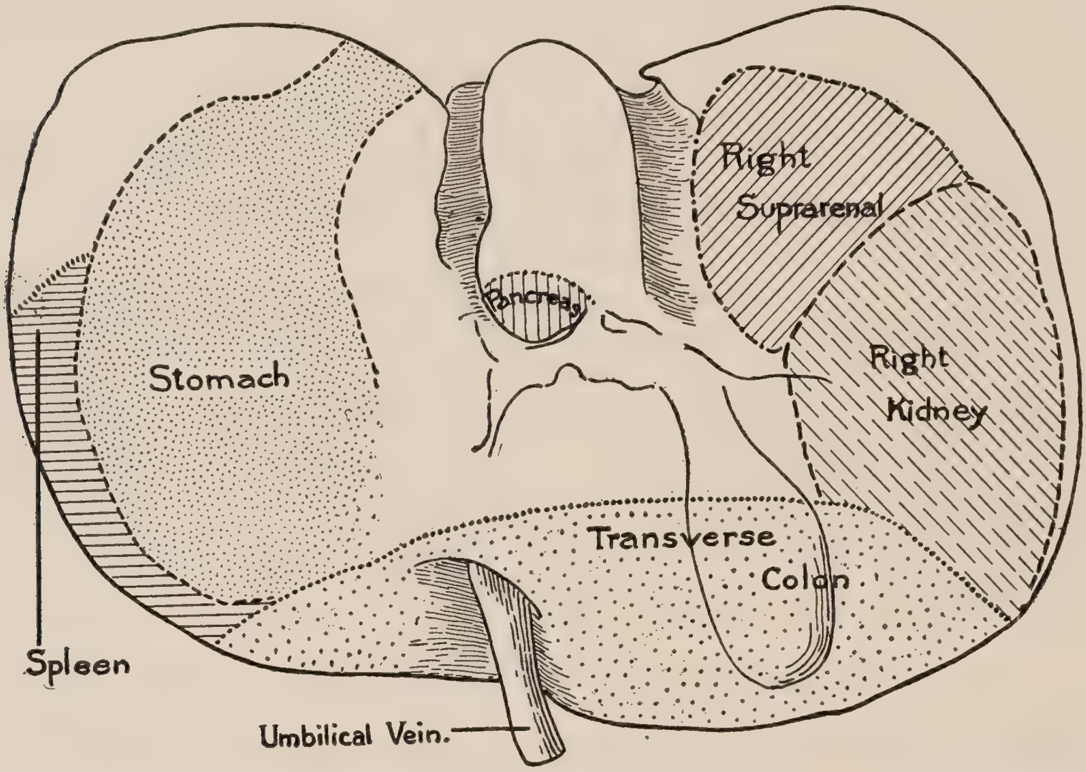

FIG. 127.—An outline of the interior surface of the liver of a newborn child 50 cm. long, showing areas of visceral contact. Natural size.

Several tabulations have been published of the dimensions of the liver in childhood as determined by palpation and percussion. Among the more important are those of Dauchez,[76] and of Frerichs.[88] The latter is quoted below.

TABLE 14.—THE VERTICAL DIAMETER OF THE LIVER IN CENTIMETERS AS DETERMINED BY PERCUSSION (AFTER FRERICHS[88])

Age	At right axillary line	At right mammary line	At right sternal line
Under 2 years	4.5	3.8	2.4
2 to 6 years	5.8	4.4	3.7
6 to 10 years	7.5	6.8	3.3
10 to 15 years	7.1	7.6	4.4
15 to 20 years	8.9	8.9	5.9
20 to 40 years	9.4	9.5	5.8

Although the left lobe of the liver is somewhat larger relatively in early life than in maturity, this difference has apparently been greatly exaggerated. Kovalski's[120] series of weighings indicate that the left lobe forms a little over one-third of the organ in the newborn and young infant and from one-third to one-fourth in later childhood and adolescence. Probably most of the apparent decrease in the relative size of the left lobe as seen in situ in the abdomen is due to the shifting relations of the organ during early life.

At birth the liver fills about two-fifths of the abdominal cavity. Its anterior surface occupies practically all of the right hypochondriac as well as a considerable portion of the upper umbilical and left hypochondriac region. On the right side its inferior margin lies about 1 to 1.5 cm. above the right iliac crest. From this point it extends upward and to the left, to pass under the left costal arch at the level of the seventh to tenth rib. The inferior margin is slightly convex from above downward and usually lies about 1 cm. above the umbilicus in the mid-line. The upper margin of the liver generally lies at the level of the fifth or sixth rib on the right and the sixth or seventh rib on the left side. According to Ballantyne[1] the anterior surface of the liver in the normal newborn infant corresponds in vertical extent to the last four thoracic and the first two lumbar vertebræ.

The visceral relations of the inferior surface of the liver in the young infant are illustrated in Figs. 127, 156. The lower surface of the left lobe is in contact with the spleen, stomach, lower part of the esophagus, a small portion of the transverse colon, and sometimes a little of the left suprarenal. The right lobe is in contact with the right kidney and suprarenal, and a large part of the transverse colon. The pancreas comes in contact with the papillary process of the caudate lobe, and the duodenum touches the posterior margin of the quadrate lobe or the porta. The areas of contact of the stomach and transverse colon vary greatly with the distension and contraction of these structures. Sometimes, when the colon is considerably contracted, the small intestines come in contact with a large part of the lower surface of the right lobe. In cases of incompletely descended cecum both this structure and the ascending colon form distinct impressions on the inferior surface of the liver.

Accurate studies, by modern anatomical methods, of the topography of the liver in later childhood are practically lacking because of the great difficulty in securing normal and well preserved material. The reconstructions of Symington which are reproduced in Figs. 122, and 123 give some idea of the position of the viscus in the middle years of childhood but the liver in the older individual (Fig. 123) is distinctly enlarged. Studies of the topography of the liver by means of percussion and palpation have generally shown that the anterior surface of the organ is gradually covered more and more by the diaphragm and costal arches, and that the anterior surface of the left lobe becomes relatively much smaller. However Cruchet and Sérége,[74] examining 160 cases, found that the inferior margin of the right lobe rapidly approaches the right costal margin until the second year when it again begins to descend until about the middle of the second period of childhood. After this time, a second period of ascent occurs ending in adolescence with the right liver margin at the usual normal adult position. These authors found much more variation in the topography of the right lobe than the left lobe of the liver. The descent of the right margin after the first year is possibly due in part to the change from a milk to a mixed diet, which has been shown to increase the volume of the liver, and in part to the effect of gravity after the erect posture becomes habitual. Figures 130, 131 show the results of these authors in graphic form.

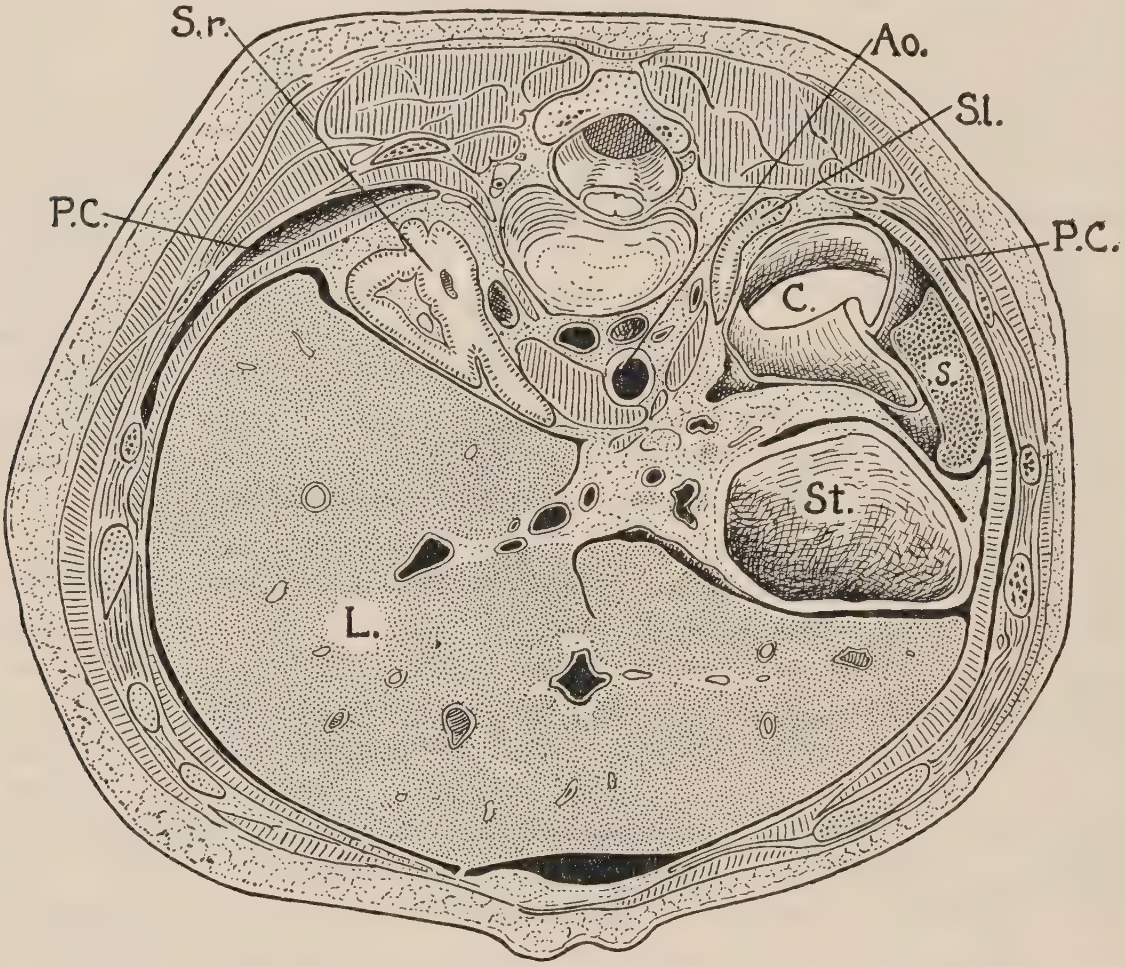

Fig. 128.—A transverse section through the upper portion of the abdomen of a full-term newborn child. Ao., aorta; C., splenic flexure of colon; L., liver; P.C., pleura cavity; S.l., left suprarenal; S.r., right suprarenal; S., spleen; St., stomach. Natural size.

The changes in the relation of the liver to the stomach and spleen are discussed in connection with these organs.

The lobular structure of the liver is not striking in the newborn or in the first few months of post-natal life, although vascular areas which will later be mapped off into permanent lobules can be distinguished. According to the observations of Kovalski,[103] the definite mapping out of the lobules takes place toward the end of the first year and the adult appearance is not acquired until after the first period of childhood. In early infancy the hepatic trabeculæ are arranged in a wide meshed network and their final radial position is only acquired as the definite lobulation of the hepatic parenchyma takes place. There seems to be some reduction in the average number of cells surrounding the bile capillaries after birth, although this change is apparently a very irregular one. According to the measurements of Toldt and Zuckerkandl,[130] the average dimensions of the liver cells are almost doubled between birth and maturity but the average size of the nuclei is slightly reduced. Cells containing two nuclei are found at birth and in early life as in maturity. Fat droplets of considerable size are found in the hepatic cells in later fetal life and at birth. Pigment granules are also present in the newborn but are not as prominent as in later life. Clusters of developing blood-corpuscles are still found in the liver at birth but disappear very shortly thereafter.

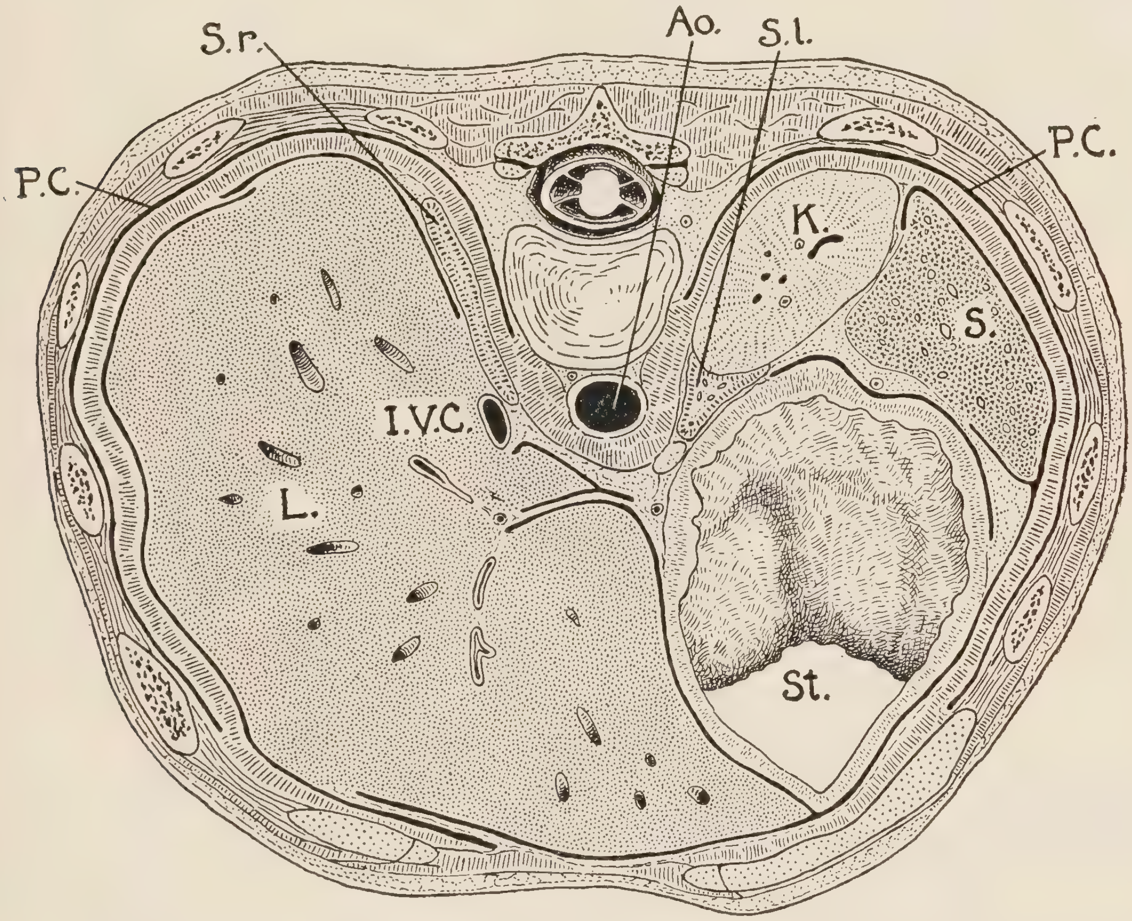

Fig. 129.—A transverse section of the upper portion of the abdomen of a girl 3 years old. Ao., aorta; I.V.C., inferior vena cava; K., left kidney; L., liver; P.C., pleural cavity; S.l., left suprarenal; S., spleen; S.r., right suprarenal; St., stomach. Two-thirds natural size. (After Dwight.[4])

At birth, hepatic parenchyma extends into the left portion of the coronary ligament and sometimes into the falciform ligament as well. This portion of the liver substance undergoes involution, probably as the result of pressure. Some remoulding of the liver, through the involution of certain parts, probably takes place after birth but the greater part of this process undoubtedly is accomplished in later fetal life. As has been remarked, the concept of a pronounced degeneration of the left lobe in post-natal life is not supported by the observations of Kovalski.

The gall-bladder of the young infant is relatively small. It is usually more embedded in the liver substance than in later life and has a proportionately smaller peritoneal surface. At this time the sac may be crossed by bands of hepatic substance which in many cases undergo involution in later life. Often the fundus does not extend to the margin of the liver at birth. Geptner (quoted by Gundobin) found that the capacity of the gall bladder increased very rapidly in the first two years during which time it acquired the same relative size, in comparison to the liver weight as in the adult. Thereafter the increase in liver weight and gall-bladder capacity is proportional.

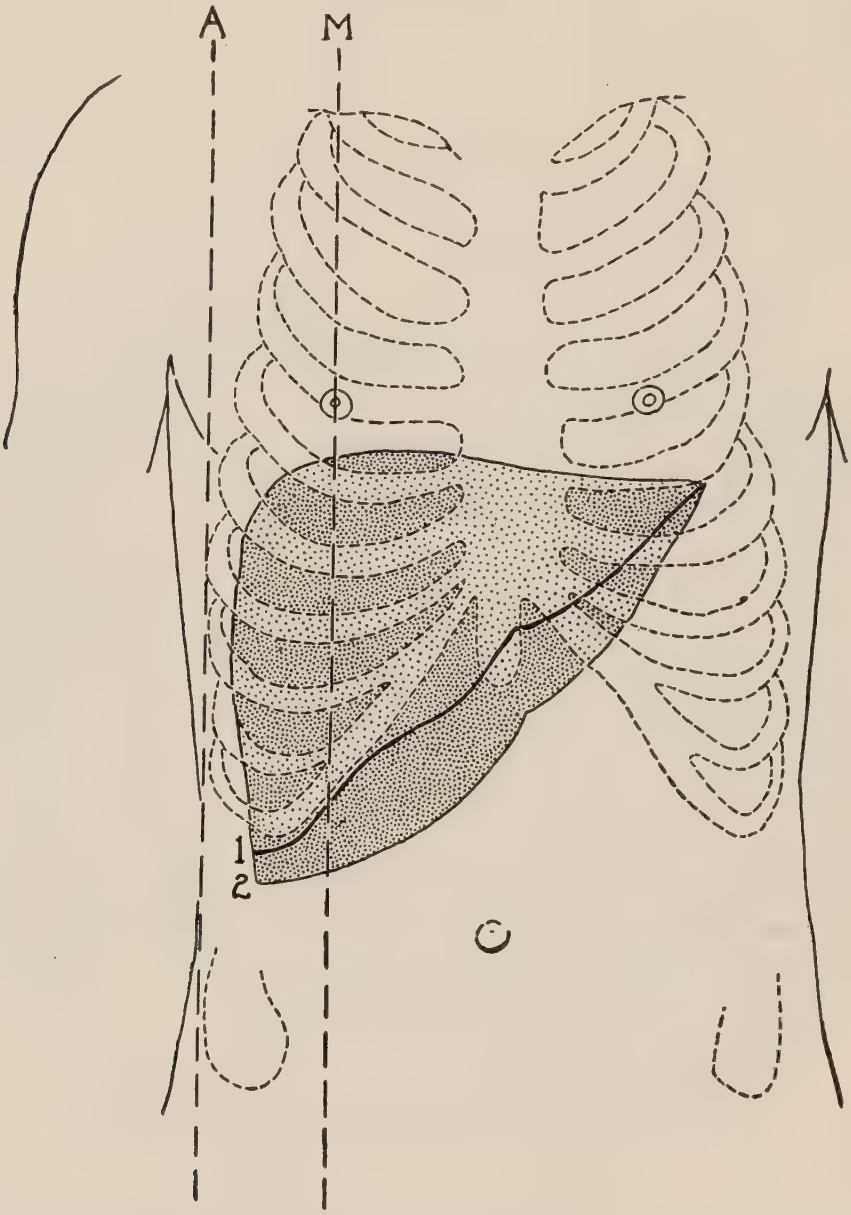

Fig. 130.—A diagram illustrating the position of the liver in childhood as determined by percussion: 1, position of liver in second year; 2, position of liver in later childhood. A, axillary line. B, mammary line. (After Cruchet and Sérége.[74])

THE RESPIRATORY SYSTEM

THE NOSE AND PARANASAL SINUSES (Figs. 107, 133, 135, 137)

An even moderately full discussion of the post-natal development of the nose and paranasal sinuses would require an amount of space and illustration which is not available in a summary like the present one. I shall therefore limit my description to a bare outline of the subject, referring the reader to the accounts of Disse,[144] Davis,[143] Killian,[149] Onodi,[155] Schaeffer[159, 160, 161] and Torrigiani[163] for detailed information.

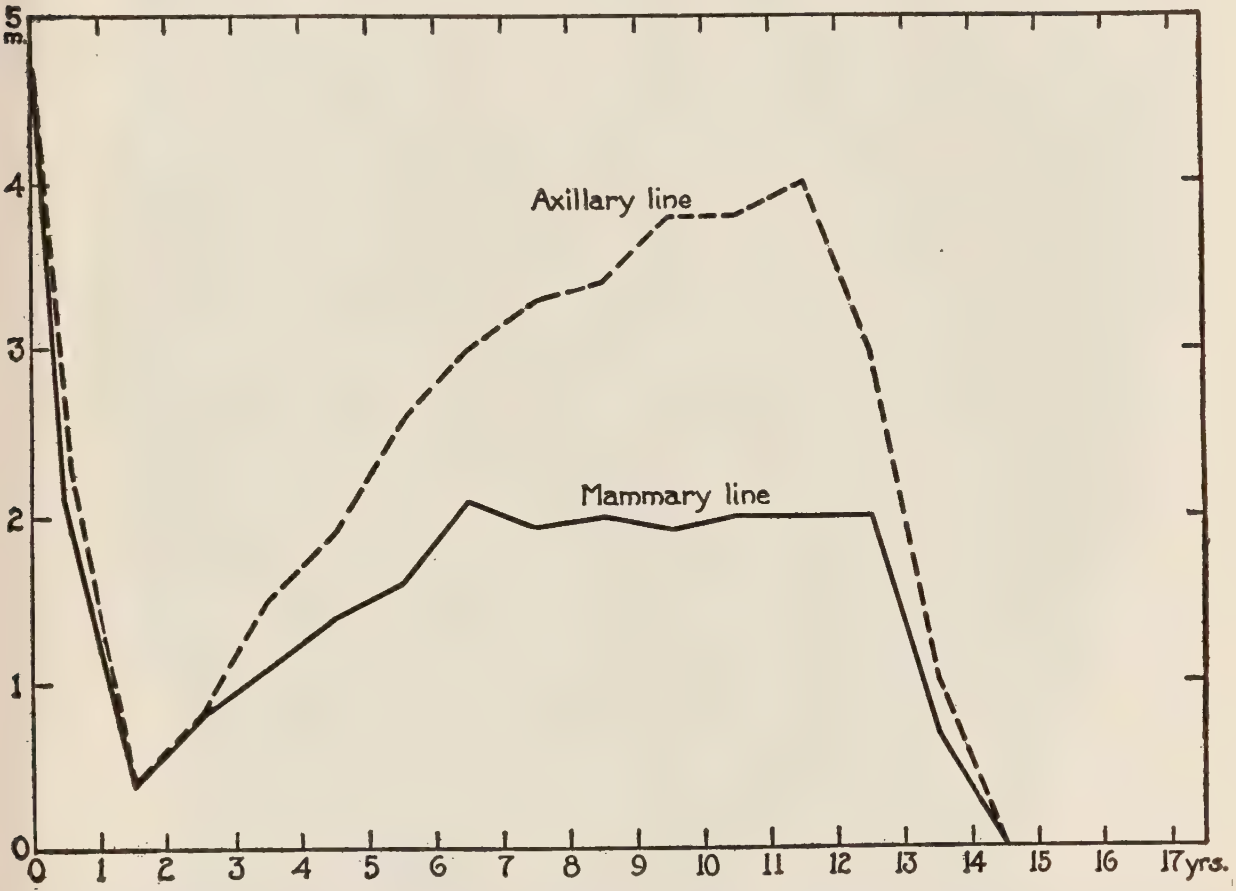

FIG. 131.—A graph showing the distance of the inferior margin of the liver below the right costal margin at different periods in childhood. (After Cruchet and Sérége.[74])

The nasal cavities of the newborn are low, broad, and relatively long. The height of the cavity, according to the measurements of Disse and Feldberg (quoted by Gundobin[7]) is 18 to 19 mm. This height increases nearly one-half in the first year but grows much slower thereafter. At seven years it is about double and in maturity from two and one-half to three times that of the infant at birth. The length or anteroposterior diameter of the nasal cavity is difficult to measure accurately. Judging from measurements of the hard palate at the median line it is doubled in the first seven years and after this time grows very little. The transverse diameter of the cavity measured at its base is about 7 mm. in the newborn, it increases very slowly to about 9.5 mm. in the first five years, and is about doubled by maturity. The nasal cavity may be divided into ethmoid and maxillary

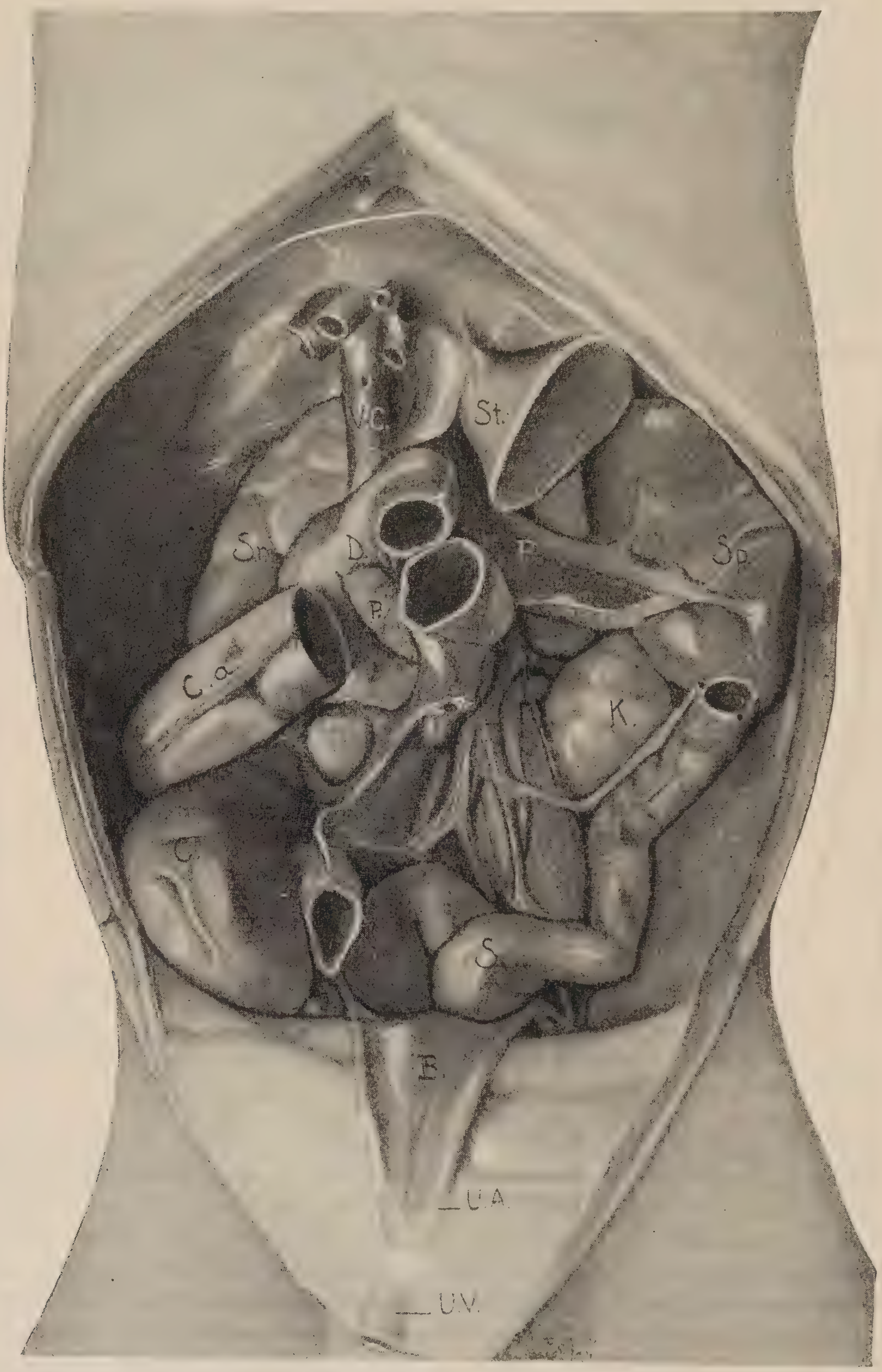

FIG. 132.—Dissection of the posterior abdominal wall of a newborn child that had lived about ten hours. The liver, the greater part of the small intestine, the transverse colon and the greater part of the stomach have been removed. B., bladder; C., cecum; C.a., ascending colon; D., duodenum; K., kidney; P., pancreas; S., sigmoid colon; Sp., spleen (somewhat enlarged); S.r., right suprarenal; St., cardiac end of stomach; U.A., umbilical arteries; U.V., umbilical vein; V.C., vena cava inferior. Natural size.

portions corresponding respectively to the parts bounded by these bones. The ethmoid part forms approximately two-thirds of the nose at birth. During the first year the maxillæ grow very rapidly and from the second year on the two portions are about equal in height.

The nasal conchæ are all differentiated during fetal life and the upper ones, the conchæ suprema I, II and III of Schaeffer, are often better marked in the fetus and newborn than in the adult. For the details regarding their form and divisions the reader is referred to the work of Schaeffer and of Davis, and for statistics regarding their postnatal growth to Disse and to Feldberg. The lower margin of the inferior concha is frequently in contact with the floor of the nasal cavity at birth, and a functional inferior nasal meatus can hardly be said to exist during the first year or two of post-natal life. The nasal septum is long anteroposteriorly and low vertically in the young infant. At this time it is composed almost entirely of cartilage. The septum is straight at the time of birth and for several years thereafter. Its frequent deviation in later life has been explained both on the basis of its rapid growth (as compared with the lateral walls of the nasal cavity) and also on the basis of the irregular eruption of the median incisor teeth (Mosher[153]). Small parallel ridges representing septal concha are sometimes found on the septa of newborn children.

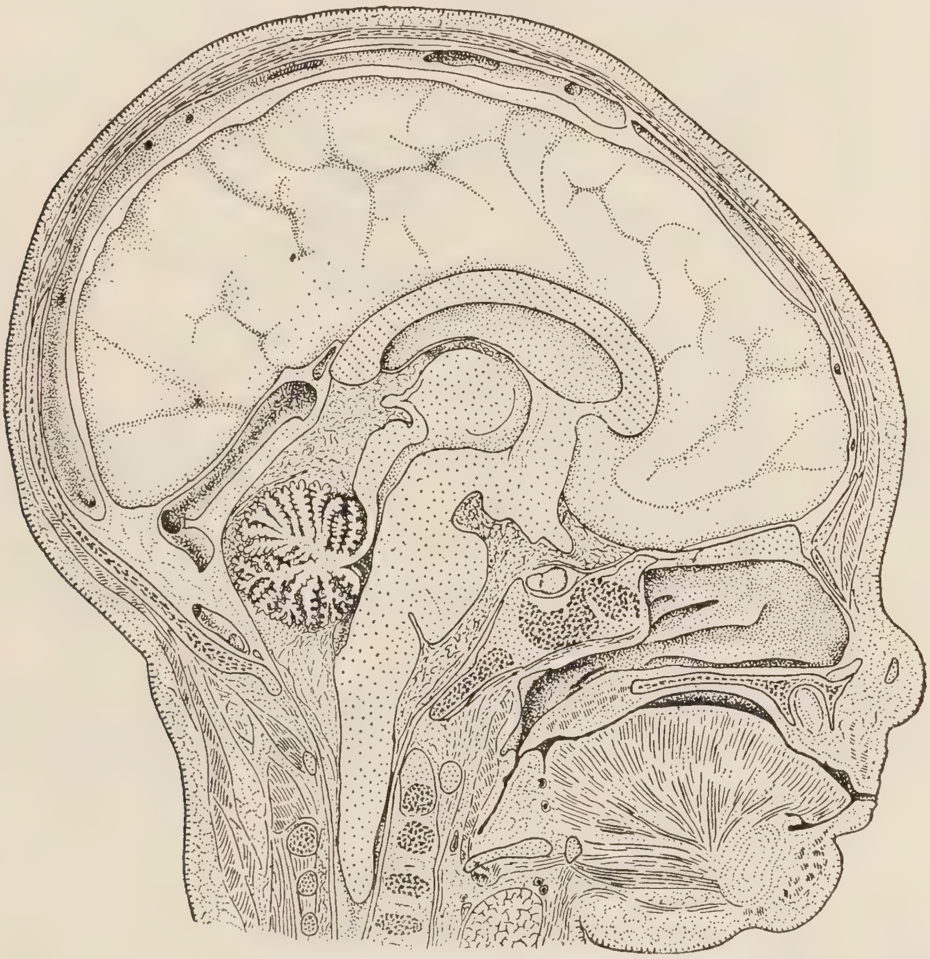

FIG. 133.—A median sagittal section of the head of a full-term, newborn child. Natural size. Figure 134 is an outline drawing of a part of the same section identifying the principal structures.

The height and breadth of the posterior nares or choanæ are about equal at the time of birth (5 to 7 mm.). According to Disse, these openings double in size in the first six months, remain stationary until the end of the second year, and then enter on a second period of rapid growth. The height of the openings increases much more rapidly than the breadth and the ratio between height and breadth, which is about 1:1 at birth, is about 3:2 at three years and 2:1 in the adult.

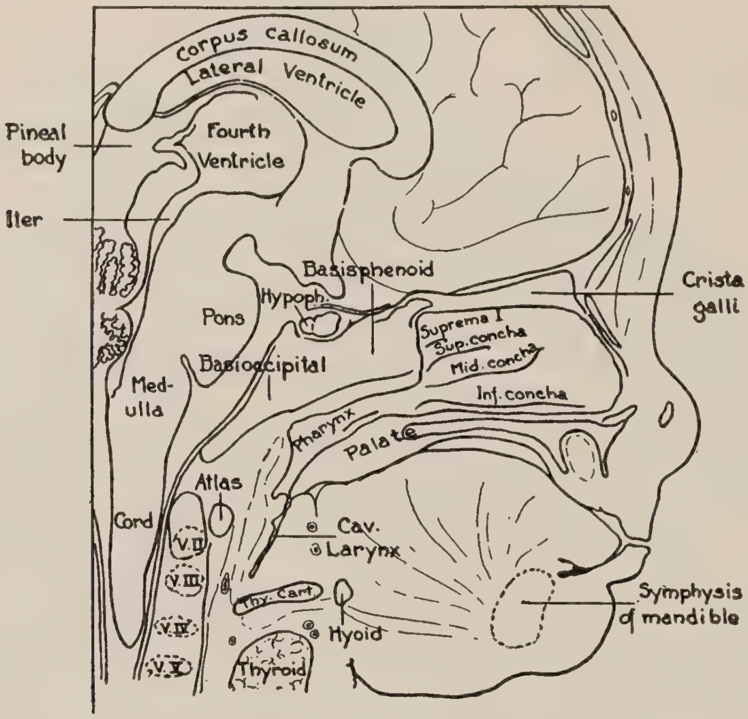

FIG. 134.—An outline drawing of a portion of the section shown in Fig. 133 with identifications of the chief structures.

THE MAXILLARY SINUS

The maxillary sinus, or antrum of Highmore, arises in the third month of fetal life as a small outpouching from the lateral wall of the ethmoidal infundibulum. The neck of the pouch remains small and forms the ostium maxillare while the distal portion enlarges to form the sinus proper. The form of the sinus is dependent on that of the maxilla which it soon invades. At birth it is a cavity from 8 to 10 mm. in length anteroposteriorly and 3 to 5 mm. in diameter transversely and vertically. The growth of the sinus in post-natal life proceeds parri passu with that of the body of the maxilla. According to Davis, its anteroposterior diameter increases about 3 mm. per year and the vertical and transverse diameters about 2 mm. per year until the eighth year of life. After the eighth year the growth of the sinus is slower in all directions until the fifteenth to the eighteenth year when the adult type is approximately reached. While the sinus is almost tubular in the newborn and young infant it is more or less ovoid in the earlier part of childhood; its pyramidal form is acquired after the erruption of the permanent dentation. At birth the floor of the maxillary sinus lies distinctly above that of the nasal cavity. It descends slowly during the greater part of childhood. Table 15 is a summary of the extensive series of measurements of the sinus published by Davis.

TABLE 15.—THE GROWTH OF THE RIGHT MAXILLARY SINUS
(Summarized from the Tables of Davis[143])

Age	Number of cases	Diameters in millimeters		
		Vertical	Transverse	Antero-posterior
8 days to 1 yr	10	5.4	4.7	13.4
1 to 3 yrs	18	8.6	7.2	18.9
3 to 6 yrs	17	12.2	11.9	24.7
6 to 9 yrs	18	19.0	16.4	28.4
9 to 12 yrs	5	20.5	17.4	28.7
12 to 15 yrs	5	22.7	17.1	24.9

THE SPHENOIDAL SINUS

The sphenoidal sinus arises in the early part of the third fetal month from the upper and posterior part of the spheno-ethmoidal recess. The sinus is well marked although minute at birth. It grows rather slowly during the first four or five years of life. After the fifth year its growth is much more rapid and its adult dimensions are attained early in adolescence. Davis has pointed out that at first the sinuses grow faster posteriorly and laterally than they do medially. As a result the septum separating them is much thicker in the infant than in older children or adults.

TABLE 16.—THE GROWTH OF THE RIGHT SPHENOIDAL SINUS
(Summarized from the Tables of Davis[143])

Age	Number of cases	Diameters in millimeters			Thickness of septum, millimeters
		Vertical	Transverse	Antero-posterior	
8 days to 1 yr	10	2.8	2.0	1.6	7.0
1 to 3 yrs	18	4.8	3.7	2.3	7.3
3 to 6 yrs	17	6.3	5.2	4.1	6.1
6 to 9 yrs	18	11.9	8.9	9.1	3.3
9 to 12 yrs	5	11.4	11.3	10.8	1.2
12 to 15 yrs	5	15.3	13.1	13.1	2.9

THE FRONTAL SINUS

The frontal sinus arises from the anterior and superior extension of the middle nasal meatus which is known as the frontal recess. The frontal recess can be found as early as the end of the third or the beginning of the fourth fetal month but the definitive frontal sinus is only occasionally recognizable at birth, and may not be present until the second or the third year of post-natal life. The exact method of origin of the sinus varies in different individuals. It may arise as an extension of the entire frontal recess; from one of the anterior ethmoidal cells; or, rarely, from the ethmoidal infundibulum (Killian,[149] Schaeffer[161]). Many of the variations in the adult sinus can be explained upon the basis of this variation in its method of origin. The post-natal growth of the sinus is illustrated by the summary of Davis' table quoted below. The sinus generally begins its invasion of the vertical portion of the frontal bone in the second year; and from two to six years its superior margin lies 1.5 to 5 mm. above the nasion. Its

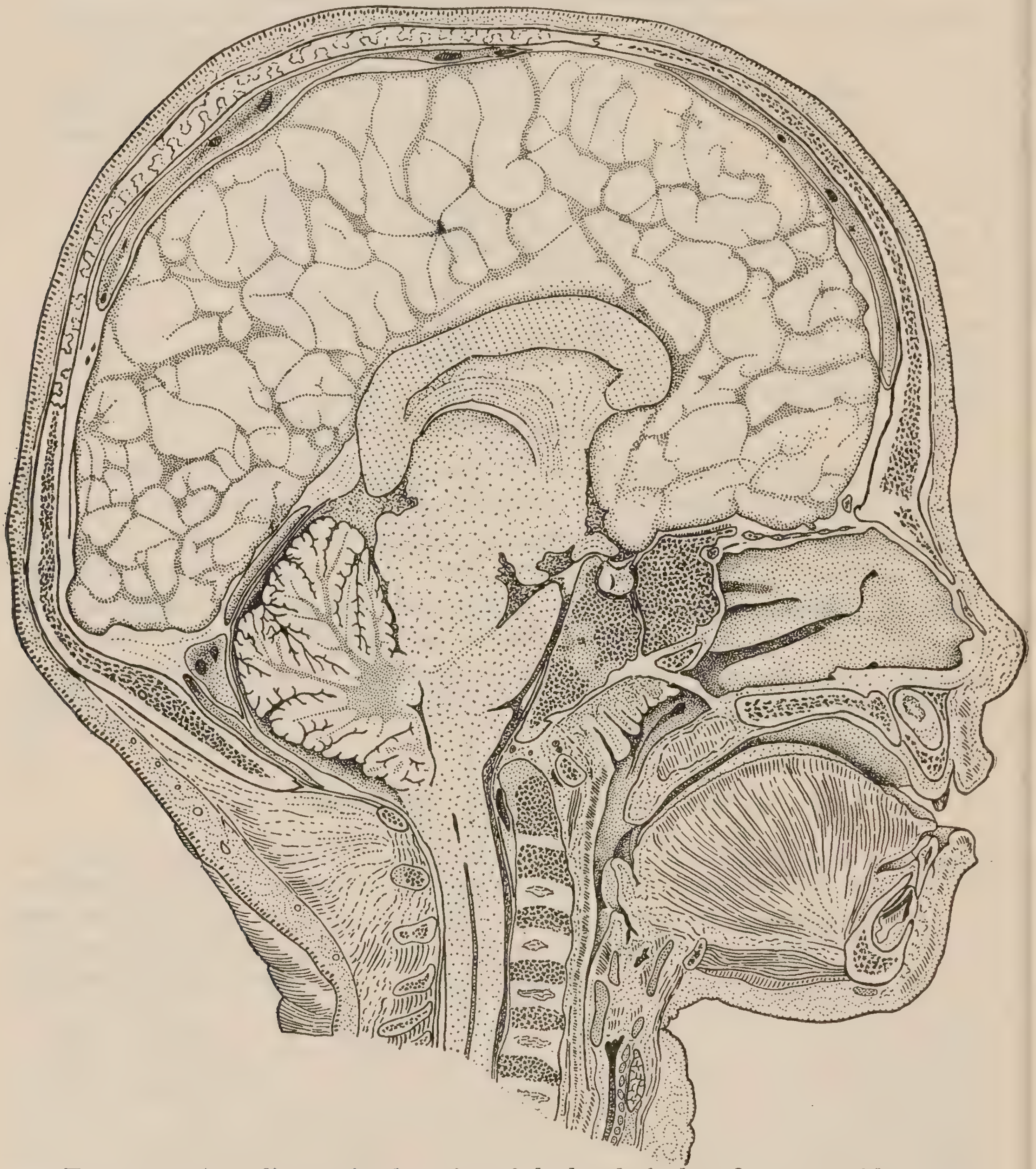

FIG. 135.—A median sagittal section of the head of a boy five years old. Three-fifths natural size. Fig. 136 is an outline drawing of a part of same section identifying the principal structures. The persistent basi-pharyngeal canal seen in this specimen is an unusual anomaly.

ascent is more rapid after this time but the adult position of the superior margin (about 25 mm. above the nasion) is not generally acquired before the sixteenth year. Davis found the average thickness of the anterior bony wall of the sinus in the first year to be 4 mm., and of the posterior 2 mm.; but as the sinus expands the bone surrounding it is resorbed so that these measurements are usually reduced about one-half by maturity.

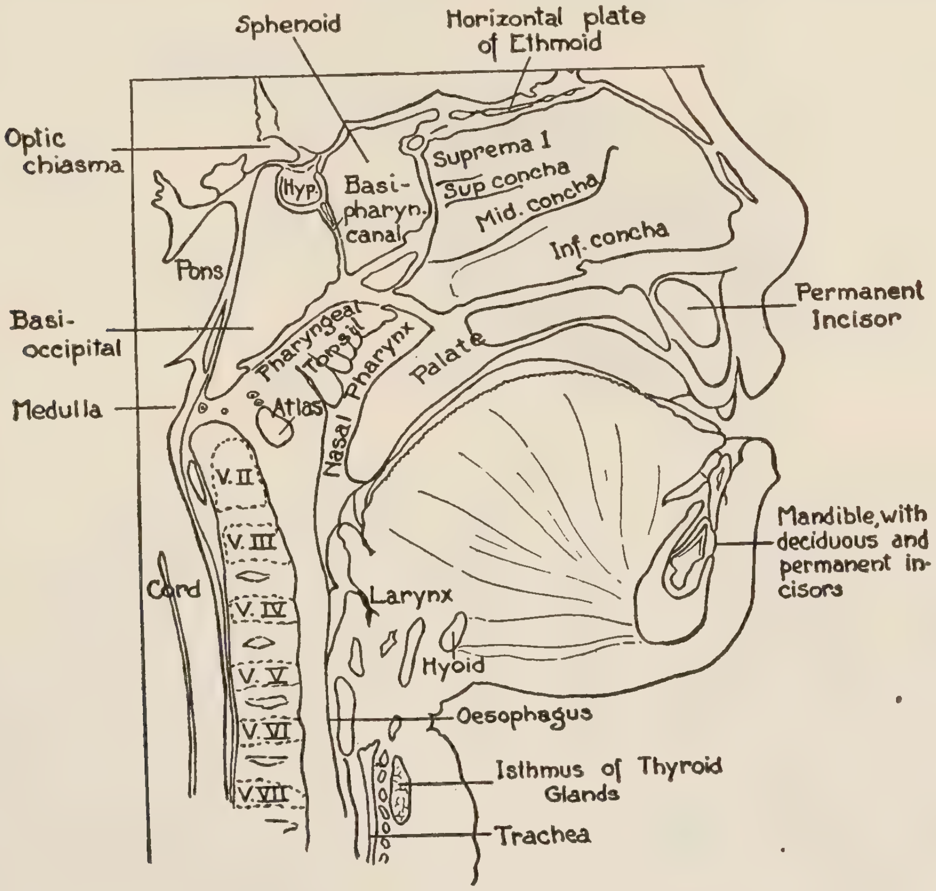

FIG. 136.—An outline drawing of a portion of the section shown in Fig. 135 with identifications of the chief structures.

TABLE 17.—THE GROWTH OF THE RIGHT FRONTAL SINUS
(Summarized from the Tables of Davis[143])

Age	Number of cases	Diameters of sinus in millimeters			Thickness of anterior wall, millimeters	Thickness of septum, millimeters
		Vertical	Transverse	Antero-posterior		
8 days to 1 yr. . .	10	2.7	1.6	3.3	4.0	9.6
1 to 3 yrs.	18	5.3	3.0	4.7	3.7	9.8
3 to 6 yrs.	17	6.8	4.1	6.0	4.4	8.7
6 to 9 yrs.	18	10.0	6.3	8.6	3.1	4.8
9 to 12 yrs.	5	11.2	8.5	7.8	3.1	5.5
12 to 15 yrs.	5	13.9	17.1	12.2	3.1	2.4

THE ETHMOIDAL SINUSES

The ethmoidal sinuses arise from grooves and recesses in the lateral walls of the middle and superior nasal meati. These invaginations are formed in the latter part of the third and the fourth fetal month and definite cells are present by the sixth fetal month. For their later development, which is extremely variable, I must again refer the reader to the studies of Davis and of Schaeffer.

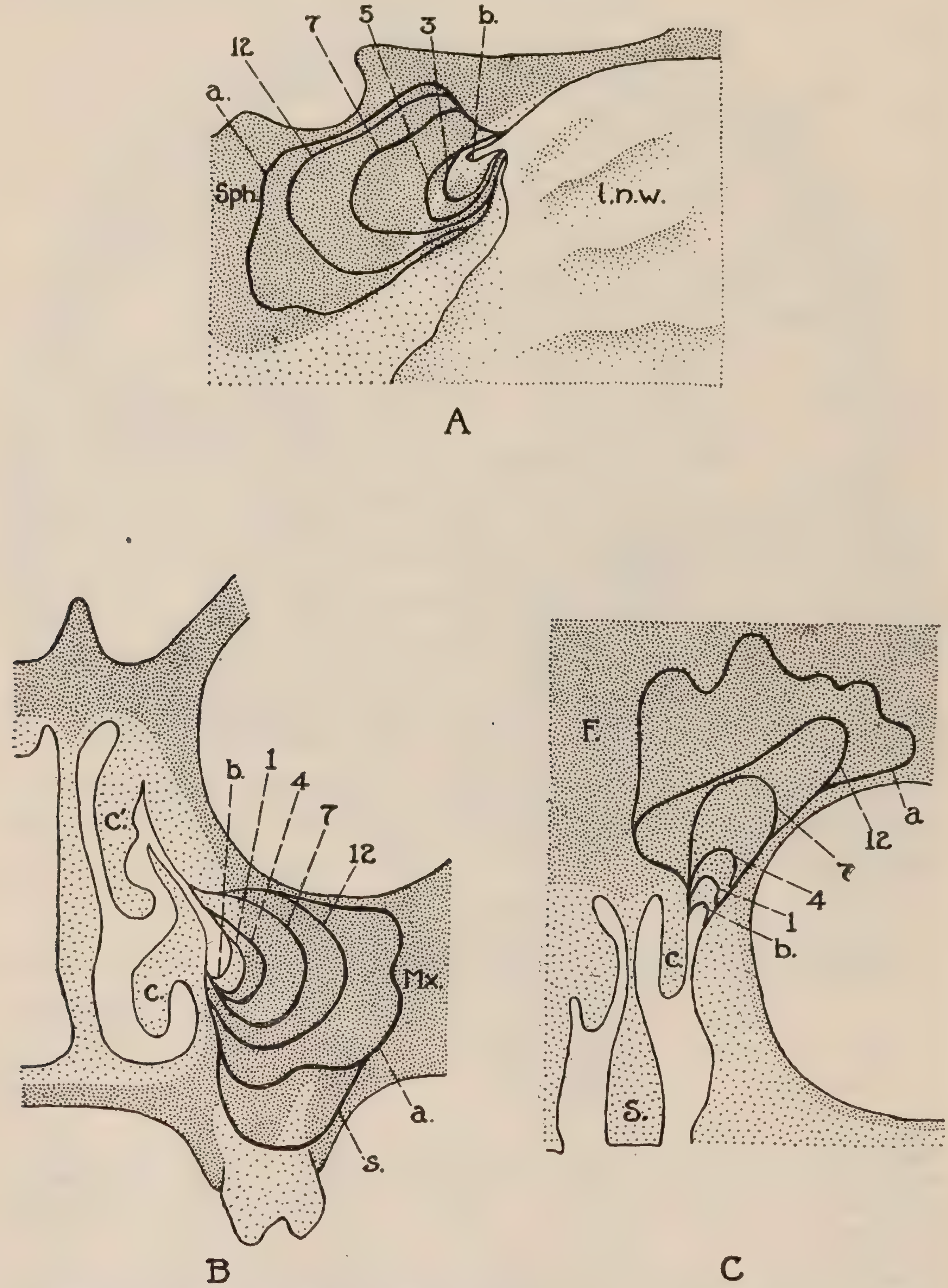

FIG. 137.—Three diagrams illustrating the post-natal growth of the paranasal sinuses. A., sphenoidal sinus; B., maxillary sinus; C., frontal sinus. c.–c'., conchæ; F., frontal bone; l.n.w., lateral nasal wall; Mx., maxilla; S., nasal septum; Sph., body of sphenoid bone. Solid black lines indicate the extent of the sinus at different ages. The Arabic numerals indicate age in years; "b" indicates birth; "a," maturity; "s," senility. (After Torrigiani.[163])

The Larynx (Figs. 133, 135, 138, 139)

The larynx of the newborn is approximately 2 cm. in length. Its maximum breadth, at the upper margin of the thyroid cartilage, is almost equal to its length. The absolute dimensions of the larynx at birth are approximately one-third those of the adult but relatively it is as large if not larger than in maturity.

The external form of the larynx is more rounded in infancy than in later life. The thyroid cartilage is broader and shorter and lies almost in contact with the hyoid bone above. The lateral lamina of the thyroid cartilage meet at an obtuse angle and neither the laryngeal prominence (Adam's apple) nor the superior thyroid notch are as marked as in later life. The cricoid cartilage has much the same form as in adult life but it is tilted downward and backward so that it forms an oblique angle with the thyroid cartilage above.

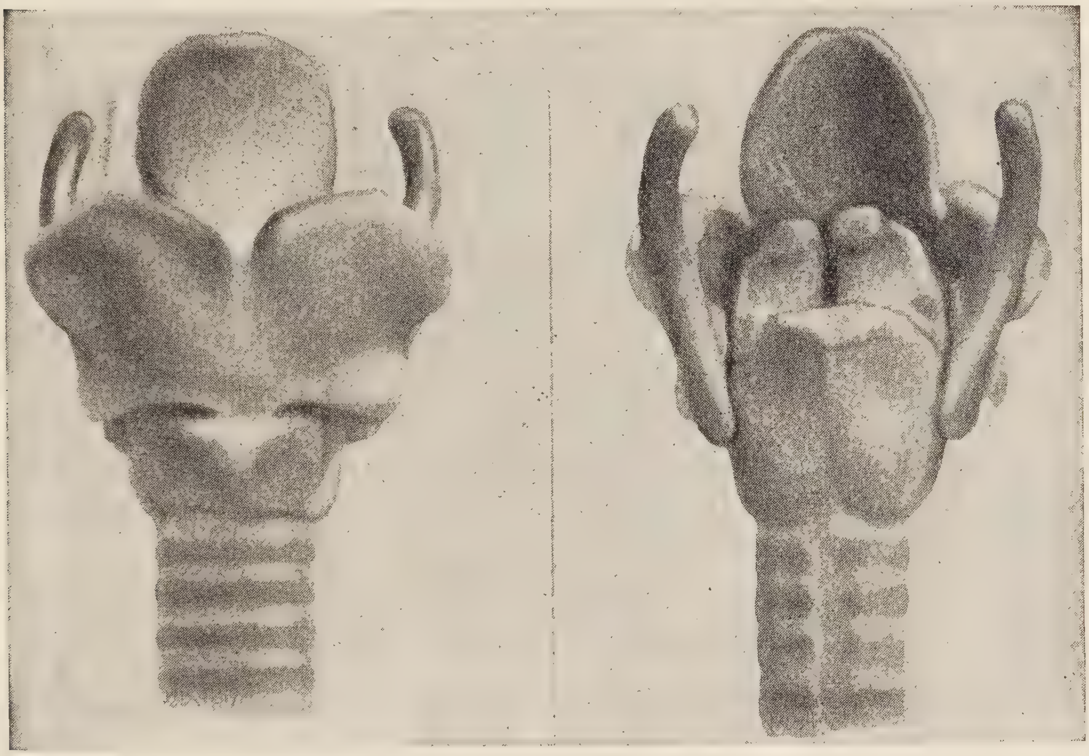

Fig. 138.—Anterior and posterior views of the larynx of a full-term, newborn male child 52 cm. long. Twice natural size.

The cavity of the larynx is short and funnel-shaped in the infant. These characters are particularly marked in the upper segment or vestibule. The true vocal cords are from 4 to 4.5 mm. in length and are relatively shorter than in later childhood and in the adult. The ventricle of the larynx is small but the ventricular appendix or saccule of Morgagni is often of considerable size. The inferior laryngeal cavity or subglottic space extends backward as well as downward in the suckling, whereas it is almost vertical in older children and in the adult. This inclination of the axis of the lower part of the laryngeal cavity is a point of some importance in connection with the procedure of intubation in the young infant.

The post-natal growth of the larynx may be divided roughly into three periods: first, from birth to two or three years, a period of rapid general growth; second, from two or three years to puberty, during which time growth proceeds rather slowly although a number of alterations in form take place; and third, the period of puberty in which growth takes place rapidly, particularly in males. At the end of the third year of life the larynx has increased approximately one-half in length and circumference, and by the time of puberty these dimensions are about double those of the newborn. During the period of puberty there is again an increase of approximately 50 per cent. in all dimensions.

Sexual differences in the larynx appear about the third year. After this time the larynx is longer and larger in boys than in girls and the angle between the lateral plates of the thyroid cartilages becomes more pronounced. These differences are accentuated during childhood and particularly during puberty when the male larynx grows much more throughout than does the female.

The larynx gradually descends in the neck during both fetal and post-natal life. According to the observations of Symington[14] and Berkenbusch,[2] the upper end of the epiglottis lies at the level of the first cervical vertebra in the newborn; at six years it is opposite the lower margin of the first or the body of the second cervical vertebra; and at puberty it is opposite the lower part of the third cervical vertebra. In the adult it lies at the level of the lower part of the third or upper part of the fourth cervical vertebra. The lower border of the cricoid cartilage lies at the level of the fourth cervical vertebra at birth; it descends to the level of the fifth or sixth by six years; and to the level of the seventh by puberty. All of these measurements were made with the head erect.

THE TRACHEA (Figs. 139, 140, 177)

The average length of the trachea in the full-term newborn is approximately 4 cm. The length in the adult is about three times that of the newborn. As in the adult, the child's trachea is broader above than below, and the frontal diameter of its cavity is slightly greater than its sagittal diameter. Both diameters increase about 300 per cent. between birth and puberty. Details of the growth of the trachea in length and caliber will be found in the following table. In this table the length of the trachea is measured from the inferior border of the cricoid cartilage to the bifurcation; and the diameters are measured in the middle third of the tube. A portion of the latter are taken from wax or metal casts; but measurements made in this way agree well with those made from the tube in cross-section.

The walls of the trachea are relatively thick at the time of birth, and the total number of tracheal cartilages are present at a comparatively early stage of fetal life. The tracheal cartilages and the annular ligaments separating them grow at the same rate during childhood. After puberty the increase in length of the trachea is apparently brought about mainly through the increasing breadth of the annular ligaments. In the child, as in the adult, the posterior membranous wall of the trachea forms about one-sixth of the circumference of the tube. The muscular layer of the membranous wall is extremely variable in thickness at all ages and is often as thick in the newborn as it is in the adult at maturity. The subepithelial and more peripheral elastic tissue layers are present at the time of birth but are comparatively weakly developed. There is a great increase in the tracheal elastic tissue during the first two years of life. The majority of the tracheal glands are present at the time of birth although possibly some are formed after that time. They do not attain their complete function until some time after birth.

Table 18.—The Dimensions of the Trachea in Childhood

(Based upon the Data of Engle, Gegovd, Koike, Mettenheimer, Oppikofer, Passavant, and Scammon)

Age	Length of trachea		Diameter of tracheal lumen		
	Number of cases	Average length, centimeters	Number of cases	Sagittal, millimeters	Frontal, millimeters
0 to 1 mo.	20	4.0	11	3.6	5.0
1 to 3 mos.	30	3.8	35	4.6	6.1
3 to 6 mos.	35	4.2	37	5.0	5.8
6 to 12 mos.	23	4.3	25	5.6	6.2
1 to 2 yrs.	17	4.5	18	6.5	7.6
2 to 3 yrs.	19	5.0	22	7.0	8.8
3 to 4 yrs.	12	5.3	12	8.3	9.4
4 to 6 yrs.	22	5.4	25	8.0	9.2
6 to 8 yrs.	14	5.7	16	9.2	10.0
8 to 10 yrs.	14	6.3	16	9.0	10.1
10 to 12 yrs.	8	6.3	10	9.8	11.3
12 to 14 yrs.	5	6.4	6	10.3	11.1
14 to 16 yrs.	9	7.2	10	12.7	14.0
Adult.	..	12 (9–15)	...	17.2(13–23)	14.7 (12–18)

The compressibility of the trachea, *i.e.*, the ability of the tube to resist external pressure, is very low in the newborn. It is about one-third that of a year old child, one-fourth that of a five year old and one-sixth that of an adult. The elasticity of the trachea in childhood, after the suckling period, is considerable; but it decreases after puberty. The extensibility of the trachea is relatively the same in childhood and maturity.

The upper limit of the trachea in the newborn and suckling lies at the level of the fourth cervical vertebra when the head is held erect. Complete extension raises it about one vertebral level, while acute flexion depresses it an equal degree. The upper limit of the trachea descends during childhood, at first rapidly and then more slowly, to reach the average adult position of the seventh cervical vertebra. There is considerable variation in the rate and degree of descent during the latter part of childhood.

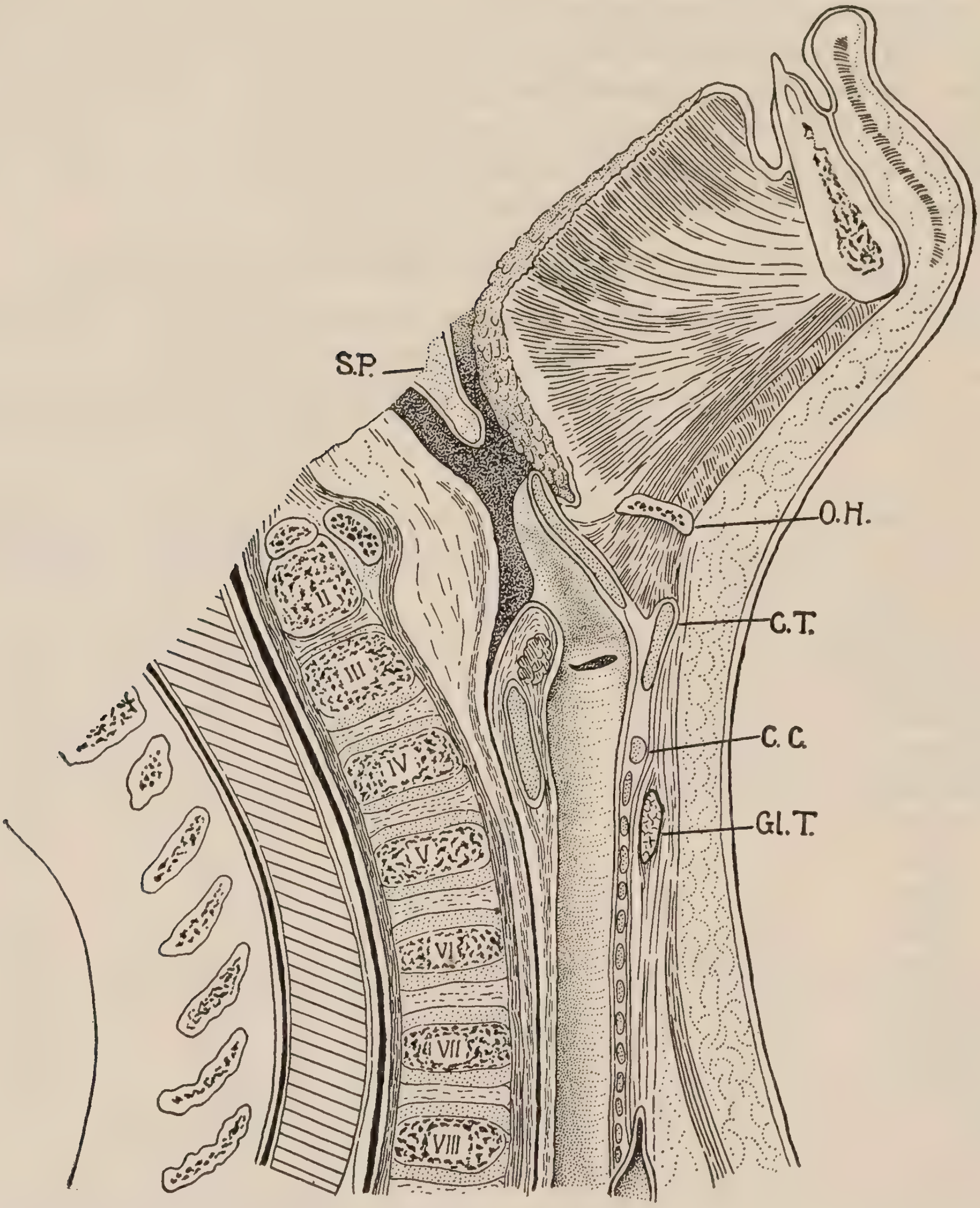

Fig. 139.—Median sagittal section of the neck of a boy two years and nine months old, with the head in extreme extension. C.C., cricoid cartilage; C.T., thyroid cartilage; Gl. T., thyroid gland; O.H., hyoid bone; S.P., soft palate. (After Passavant.[154])

The bifurcation of the trachea in the newborn lies at the level of the third or fourth thoracic vertebra. It descends very slowly the first few months but later proceeds more rapidly. The following table of the position of the bifurcation is based upon Engle's[145] radiographic studies to which the reader is referred for further details.

TABLE 19.—POSITION OF THE BIFURCATION OF THE TRACHEA IN CHILDHOOD AS DETERMINED BY THE ROENTGEN-RAY
(AFTER ENGLE)

Age	Position
0 to 2 yrs.	Lower margin of IIIrd to lower margin of IVth T. V.*
3 yrs	Middle margin of IVth to upper margin of Vth T. V.
4 yrs	Middle margin of IVth to lower margin of Vth T. V.
5 yrs	Lower margin of IVth to lower margin of Vth T. V.
9 yrs	Upper margin of Vth to middle margin of VIth T. V.
12 yrs	Middle margin of Vth to middle margin of VIth T. V.

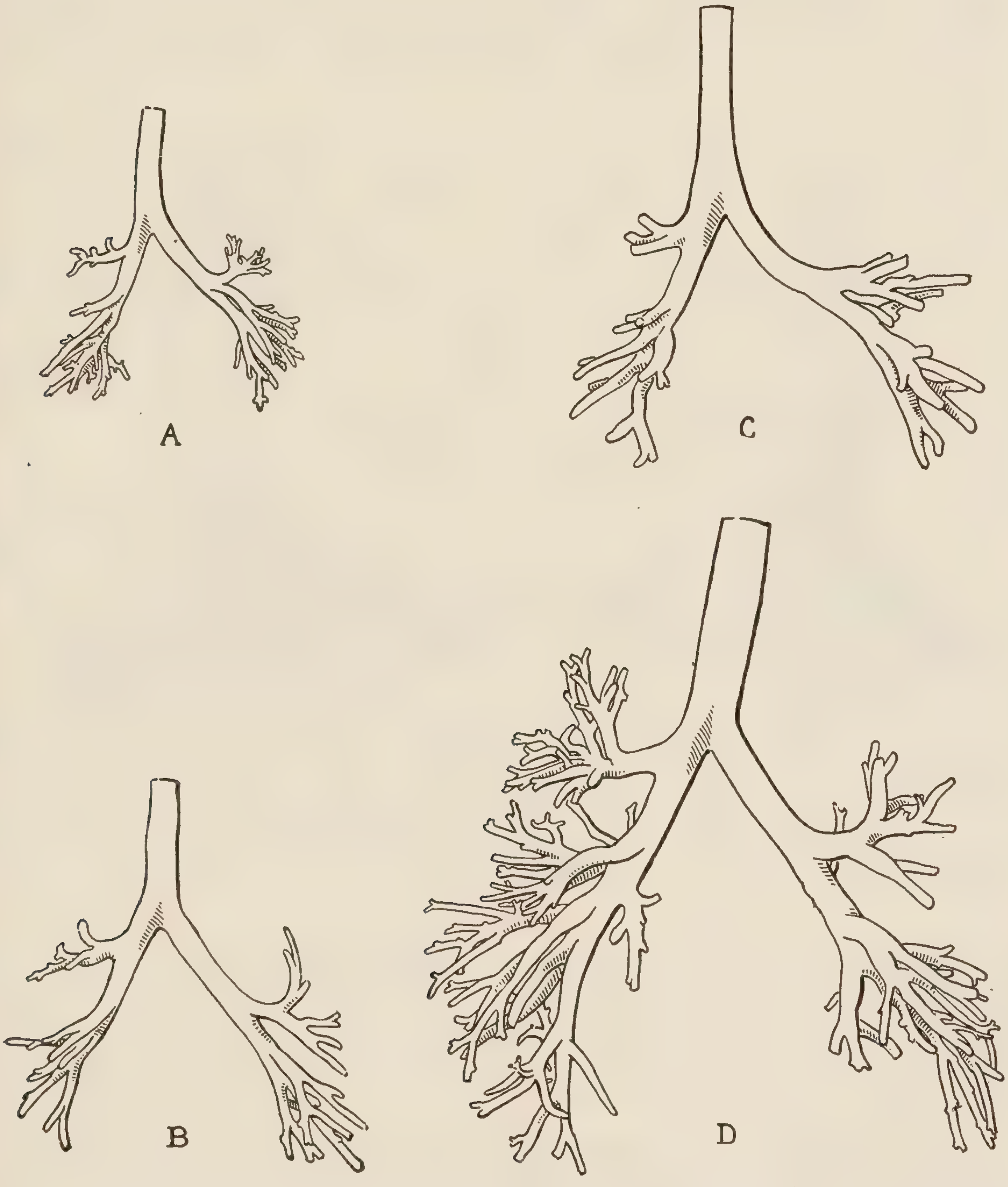

FIG. 140.—Four outline drawings of casts of the bronchial trees of children. A, child of three months; B, child of one year; C, child of three years; D, child of seven years. One-half natural size. (After Engel.[145])

*T. V., Thoracic vertebra.

The relation of the trachea to the sternum undergoes considerable change during childhood. The length of the cervical portion of the trachea (from the upper margin of the sternum to the lower margin of the cricoid cartilage) is, according to Passivant,[154] 3.6 cm. in the newborn with head erect and 4.0 cm. with the head extended. These distances increase to 7.5 cm. and 10 cm. respectively in children of 9 to 18 months.

THE LUNGS (Figs. 122, 123, 141, 142, 164, 167, 178)

The weight of the lungs in the newborn, as at all times of life, is extremely variable. The average weight in the full-term child at birth is about 50 gm. Theoretically, it might be expected that the lungs of children in which respiration had been established would be relatively heavier than those of stillborn infants, because of the influx of blood into the lungs through the expanding pulmonary arteries. As the difference in the ratio of lung to body weight in stillborn and live-born children was at one time advanced as a practical test in cases of suspected infanticide, careful and extensive studies have been made on this point. These studies have shown that if any such difference exists it is so small that it is masked in any extensive series of cases by the natural variability of the weight of the organs. The lungs increase to twice their birth-weight or more in the first six months of post-natal life and often triple their weight in the first year. The rate of weight increase of the lungs is practically the same as that of the body as a

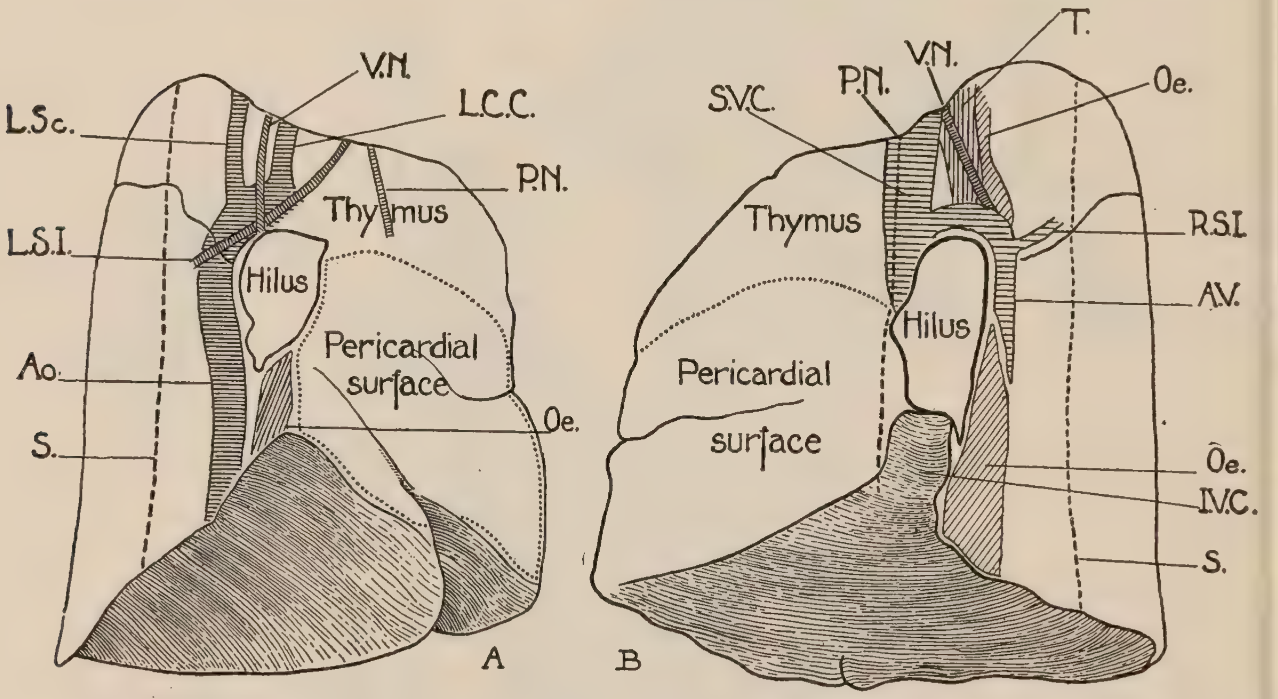

FIG. 141.—Outlines of the medial surfaces of the lungs of a newborn child showing the visceral relations. A, left lung; B, right lung. Ao., aorta; A.V., azygos vein; I.V.C., inferior vena cava; L.C.C., left common carotid artery; L.Sc., left subclavian artery; L.S.I., left superior intercostal vein; Oe., esophagus; P.N., phrenic nerve; R.S.I., right superior intercostal vein; S., line of vertebral column; S.V.C., superior vena cava; T., trachea; V.N., vagus nerve. (After Huntington.[9])

whole during the entire period before maturity. The absolute weight of the lungs in the adult is approximately 20 times that of the newborn; and the relative weight remains fairly constant throughout postnatal life.

The volume of the lungs in the newborn infant, with respiration established, was found by Aeby to be 67 c.c. The increase in lung volume like that in lung weight, keeps pace with the increment in body weight. The right lung is larger than the left from the time of formation of the lung buds in the embryo. Jackson found it to be 25 to 30 per cent. larger in the newborn, a greater difference than is generally quoted for the adult.

In the full-term stillborn infant the lungs do not fill the entire potential pleural cavity. They are in close contact with the posterior half of the mediastinum and the costal pleural surfaces; but generally they are not pressed against the anterior chest wall, and they never extend into the costo-phrenic sinus. The anterior medial borders do not extend so far towards the mid-line of the body as they do in the infant whose respiration is fully established, and the left lung is indented by a very extensive cardiac notch which often occupies fully half of its medial border. As a result of this position, the lungs of the stillborn infant are short, broad, and thin, as compared with those of the child in which respiration has been established; and while the impressions of the structures bounding their posterior parts are well marked, their anterior surfaces are often smooth except for the deep cardiac notch mentioned above. The anterior, inferior, and medial margins of the lungs are much sharper in the stillborn than in the liveborn and the inferior surfaces are much more convex because of the greater arching of the diaphragm.

With the establishment of respiration and the consequent expansion of the lungs, the shape and position of these structures is greatly changed. They increase in all diameters, but particularly in the sagittal one, along with the descent of the diaphragm. The margin of the left lung surrounding the cardiac notch gradually pushes medially between the pericardium and the sternum so that the so-called bare area of the heart is diminished. At the same time the apex of the heart is shifted downwards and to the right (probably in part through the pressure of the expanding lung) and this change in its position aids in decreasing the extent of the cardiac notch. The anterior, medial, and inferior margins of the lungs lose their sharp margins through the expansion of the peripheral alveoli of these regions. The costo-phrenic sinus, however, is not invaded by the lower lung margins to any great extent at the time of birth, this change occurring as a rule in later childhood.

As respiration is established the skeletal relations of the lungs are also somewhat modified. In the stillborn, according to Mettenheimer,[12] the summits of the lungs lie 3 to 5 mm. above the level of the superior margin of the sternum; and their bases generally at the level of the ninth or tenth rib posteriorly. After respiration the apices lie 5 to 8 mm. above the level of the superior margin of the sternum and the inferior margins lie at the eleventh rib posteriorly.

There is very little change in the skeletal relations of the lungs between infancy and maturity. The inferior margins remain fixed at the eleventh or twelfth vertebra posteriorly; but in the mammillary line there is a slow descent of the lung margin from the level of the fifth rib in the young child to the sixth rib in the young adult.

The topography of the fissures and lobes of the lungs in infancy has recently been studied in detail by Gittings, Fetterolf and Mitchell;[148] they find that the relations of the structures to the bony thorax are practically the same as in the adult.

According to Kolliker the formation of the alveoli of the lungs begins in the sixth fetal month. The number of alveoli increases rapidly until the time of birth but there is little increase in their size. The changes in the alveoli at birth have been recently reinvestigated by Addison and Howe[141] and by Ridella.[157] With the first inspiration the alveoli are enlarged and the epithelium lining them is reduced from a low columnar or cuboidal to an extremely flattened squamous type. The nuclei of the lining cells are flattened and are farther separated from one another. According to Ridella the flattening process begins at the fundus of the air-cell and extends around it from this point to the neck. As the lungs expand the fluid which occupied the trachea before respiration is drawn down into the air-cells and is distributed on the inner surface of their walls. In sections this is seen as a granular precipitate, and large mononuclear cells, possibly phagocytic in function, are found within it. The fluid is absorbed in a short time.

The expansion of the lung at birth is extremely irregular. One may find expanded and unexpanded alveoli in the same lobule; and again lobules made up of expanded alveoli may be scattered among those which show no evidences of expansion. Champneys,[142] who made a special study of this matter in connection with his researches upon the efficacy of various methods of initiating respiration, came to the following conclusions concerning the expansion of the lungs in newborn children.

1. "The right lung is usually better expanded than the left.

2. "The anterior surfaces are usually better expanded than the posterior.

3. "The lower lobes are the parts most often unexpanded.

4. "The right middle lobe is usually well expanded.

5. "The part of the left lung corresponding to the right middle lobe is often better expanded than the rest of the left lung; when the right middle lobe is ill expanded, the corresponding part of the left lung is often unexpanded also."

The production of alveoli ceases at birth except for the formation of a very small number from the walls of the respiratory bronchioles. Thus the greater part of the post-natal increase in volume of the lungs is brought about by the growth of the alveoli which are formed in fetal life. The observations of Rossignol,[158] which are quoted in Table 20 below, are the only extensive ones on the growth of the alveoli. They are based upon measurements of lungs which were inflated and dried, and a considerable degree of error may have been introduced by this procedure.

TABLE 20.—THE GROWTH OF THE RESPIRATORY ALVEOLI (AFTER ROSSIGNOL[158])

Age	Average diameter of alveoli
Children who had breathed only a few hours	0.05 mm.
Children of 1 to 1½ yrs	0.10 mm.
Children of 3 to 4 yrs	0.12 mm.
Children of 5 to 6 yrs	0.14 mm.
Children of 10 to 15 yrs	0.17 mm.
Adults of 18 to 20 yrs	0.20 mm.
Adults of 25 to 40 yrs	0.20 to 0.25 mm.
Adults of 50 to 60 yrs	0.30 mm.
Adults of 70 to 80 yrs	0.33 to 0.35 mm.

Elastic tissue appears in the lungs in the fifth or sixth fetal month. It develops very slowly until birth, but it increases with great rapidity in the first month of post-natal life.

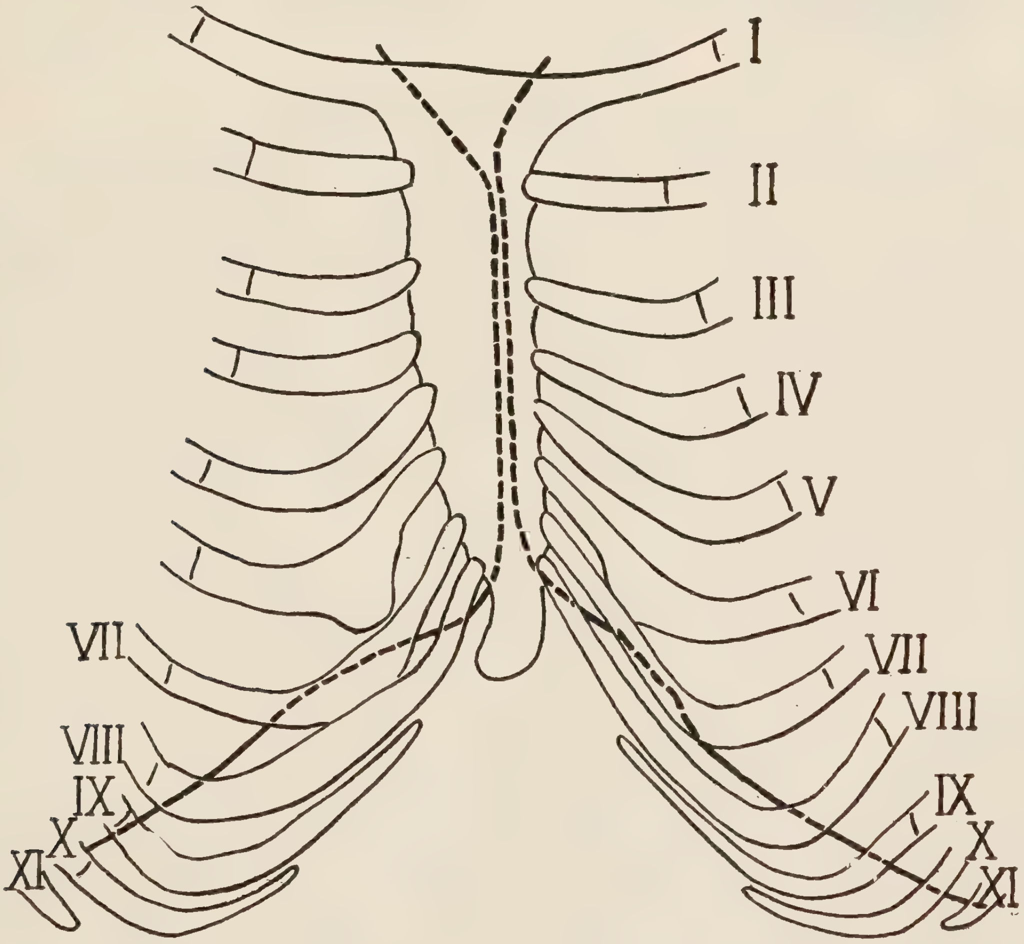

FIG. 142.—Outline of the skeleton of the anterior thoracic wall of a newborn child showing the common lines of pleural reflection in infancy. The numbers of the ribs are indicated in Roman numerals. (Based upon the figures and descriptions of Tanja.[162])

THE PLEURA (Figs. 122, 123, 142)

The only extensive series of observations upon the topography of the pleural sacs in infancy is that of Tanja[162] and the following statement is summarized from his descriptions. The medial margins of the pleural sacs generally meet behind the sternum, extending almost the entire length of that bone a little to the left of the median line. The left line of pleural reflection turns away from the sternum at the level of the sixth rib, the sixth interspace, or the seventh rib; the right one a little lower at the level of the seventh rib or along the upper part of the xiphoid process. In over one-half the cases the inferior pleural margins pass across the costal cartilages of the ribs from the seventh downward. The inferior pleural margin commonly joins the medial posterior one at the level of the twelfth thoracic vertebra. As in the adult, the posterior lateral margins of the pleural sacs extend upward to the level of the last cervical vertebra. The skeletal relations of the apices of the sacs are much the same as those of the adult. Certain variants from this general scheme are common. The anterior medial margin of the left pleural sac may not extend inward to the sternum, and sometimes the two sacs do not meet anteriorly. The posterior inferior angle of the sacs may lie as low as the first lumbar vertebra or as high as the eleventh thoracic vertebra. Figure 142 is a diagram showing the usual lines of the pleural reflections on the anterior chest wall in infancy.

THE UROPOIETIC ORGANS

THE KIDNEYS (Figs. 122, 123, 129, 132, 143, 144, 145, 147, 156)

The absolute weight of both kidneys in the newborn is between 20 and 25 gm. This weight is doubled in six months, quadrupled in the first two years, and increased about eight fold by puberty. The average weight of the kidneys in the adult is from 10 to 14 times that of the newborn. Although the absolute weight increase is great, the kidneys show a decrease in relative weight in post-natal life. At the time of birth and for nearly five years thereafter they form 0.65 to 0.75 per cent. of the entire body weight. After five years the relative kidney weight decreases slowly until after puberty when the adult relation of about 0.5 per cent. is reached. Although the kidneys are rarely of equal weight at the time of birth the examination of a large series of cases shows the right to be the heavier in almost as many instances as the left. By the second year, however, the left kidney is commonly the heavier one as it is in maturity.

At birth the kidneys average 4 to 5 cm. in length, 2 to 2.5 cm. in breadth, and 1.2 to 1.5 cm. in thickness. The length and breadth of the kidneys increase about two and one-half times by maturity and the thickness about two times. The kidneys are thus somewhat thicker proportionally in the infant than in the adult.

The most striking characteristic of the infant's kidney is its marked lobulations. These are ordinarily obliterated in the fourth or fifth year although they may occasionally persist in the adult. In certain mammals, such as the sheep and the bear, they are found throughout life. The number of lobules is extremely variable, being anywhere between 5 and 25. There is no relation between the number of lobules and the number of renal papillæ.

Both the skeletal and the visceral relations of the kidneys in the young infant are quite different from those of later life. The differences in the skeletal relations are due mainly to the large size of the kidneys and the shortness of the lumbar portion of the posterior abdominal wall. The relation of the lower poles of the kidneys to the iliac crests has been studied by Alglave,[164] who found that in a series of 32 children under six months of age the lower poles of the kidneys were below the iliac crests in one-half of the cases, on the crests in a little over one-quarter, and above the crests in the remainder. In the second year the lower poles were on the crests in one-third and above the crests in two-thirds of the cases. The lower poles of the kidneys were above the crests in all children over two years of age. The upper poles at birth, according to the observations of Baduel,[165] lie at the eleventh intercostal space or the margins of the ribs bounding it and during childhood at the level of the twelfth rib. Banchi[166] examining 100 newborn children, found that the upper poles of the kidneys commonly lie at the twelfth thoracic vertebra, or the disc immediately above and below it, and the lower pole at the fourth or fifth lumbar vertebra. In the newborn and the young infant the left kidney lies higher than the right in about two-thirds of all cases. Although the kidneys are much more movable in the child than in the adult their change in position is probably a passive one dependent upon the rapid growth of the neighboring skeletal parts and their associated muscular structures.

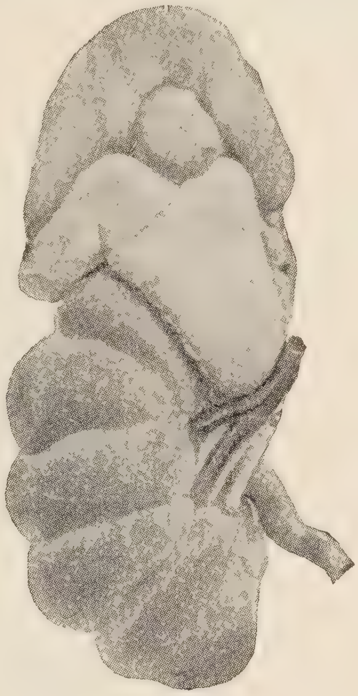
Fig. 143.—Anterior view of the left kidney and suprarenal of a newborn child 52 cm. long. Natural size.

In the infant the anterior surface of the right kidney is in contact with the cecum, the ascending colon, the right suprarenal, and the liver. Relatively the suprarenal has a much larger contact area than in later life while the hepatic area is relatively smaller. The right margin of the descending segment of the duodenum generally comes in contact with the hilus of the right kidney. The left kidney is in contact anteriorly with the left suprarenal, the descending, and, sometimes, the transverse colon. At birth and for a very short space of time thereafter the left kidney is not commonly in relation with the spleen. Occasionally the tail of the pancreas may touch the kidney just below the inferior margin of the suprarenal.

As is well known, the tubules of the kidney are formed in a series of from 14 to 18 generations. The glomeruli of these several generations are arranged, in the young kidney, in roughly concentric layers of which the inmost is the oldest in origin and the peripheral the most recent. The exact time of formation of the last or peripheral generation of tubules is a matter of considerable controversy. The date has been variously placed from the ninth or tenth fetal month to the end of the first post-natal month. Although there may be considerable individual variation in this particular, one is inclined to suspect that congenital lues may be responsible for the delayed date of cessation of tubule formation which some authors have observed in their material. The kidneys have acquired approximately one-tenth of their final weight at the time when new tubule formation ceases; it follows, then, that fully 90 per cent. of the growth of the renal parenchyma is in the form of tubule hypertrophy. Our knowledge of the nature of the post-natal changes in the renal tubules rests mainly on the micrometric studies of Eckardt[169] and of Külz.[175] These observations show that the central or older glomeruli are very much larger than the peripheral ones at the time of birth. The central glomeruli grow steadily in size until after puberty by which time they

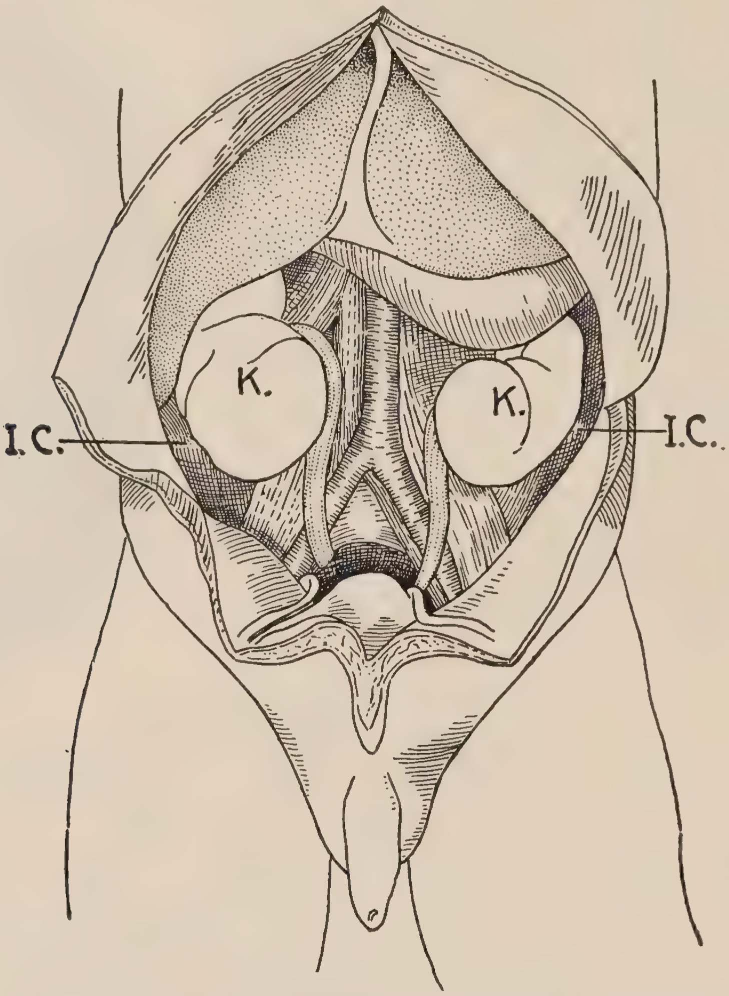

FIG. 144.—A dissection of the posterior abdominal wall of a male child one month old showing the position of the kidneys. I.C., iliac crest; K., kidney. (After Alglave.[164])

have doubled in diameter. The peripheral glomeruli grow at a more rapid rate than do the central ones; but do not equal them in size until after puberty. The ascending and descending limbs increase but little in diameter between birth and maturity. The most active segments are the convoluted tubules. These increase in diameter very rapidly during the first three or four years of life. Thereafter their diameter increases very little, but they enter a period of longitudinal growth which lasts until after puberty. The growth of the collecting tubules is apparently slight.

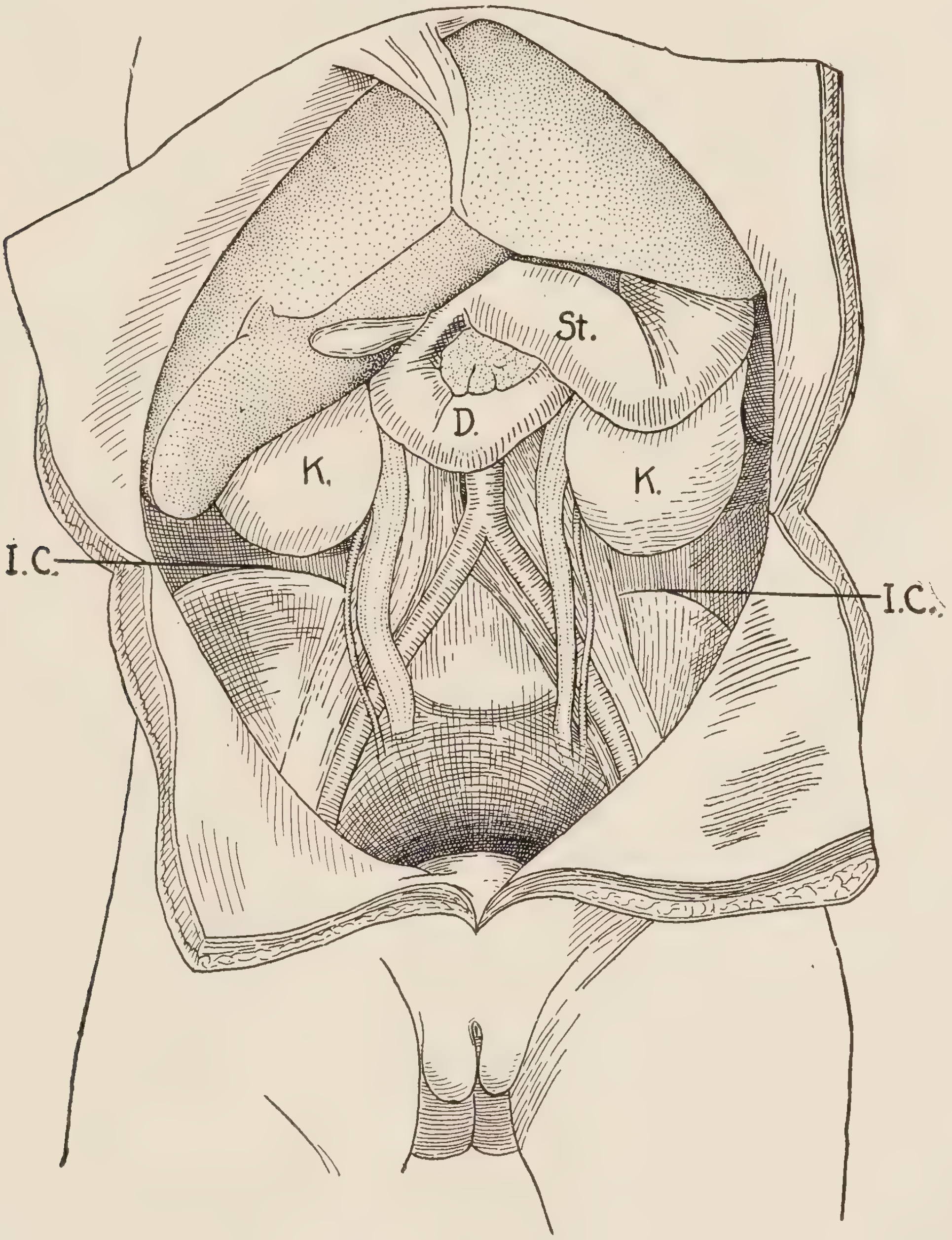

Fig. 145.—A dissection of the posterior wall of the abdomen of a girl two and one-half years old showing the position of the kidneys. D., duodenum enclosing the head of the pancreas; I.C., iliac crest; K., kidney; St., stomach. (After Alglave.[164])

No volumetric studies have been made of the cortex and medulla in childhood. In the newborn the cortex is one-fifth or one-fourth the thickness of the medulla and in the adult from one-half to two-thirds. Apparently most of the increase in thickness of the cortex takes place in the first eight years of life. Lineal measurements of the cortex and medulla are very inaccurate and the proportions just citied are only approximate ones.

THE URETERS (Figs. 144, 145, 147, 148)

The ureters are from 6.5 to 7.0 cm. in length in the newborn, being a little less than one-fourth as long as in the adult. The left ureter is generally a little longer than the right throughout life. The ureters practically double in length during the first two years together with the growth of the lumbar region; thereafter their growth is much slower. The diameter of the ureter in the infant is always relatively and sometimes absolutely larger than in the adult. The sinuses of the ureter are well marked and the lumbar one, in particular, is very prominent (Fig. 147).

THE BLADDER (Figs. 121, 132, 146, 147, 151, 153)

In the newborn and young suckling the contrated bladder is a fusiform organ broader below and tapering very gradually above, becoming continuous with the obliterated urachus at its apex. It is in contact with the anterior body wall over a triangular area of which the base is formed by a horizontal line drawn a little below the upper margin of the symphysis pubis, and the sides by the hypogastric arteries. The apex of the contracted bladder in the newborn lies at a point mid-way between the pubes and the umbilicus. The long axis of the bladder in the infant is often nearly vertical and falls directly in line with that of the prostatic urethra, or at most forms a wide angle with it. The thickest part of the contracted bladder in the newborn lies at about the level of juncture of its lower and middle thirds. From this plane all the surfaces of the organ slope downward and inward toward the urethral orifice. Thus the lower part of the viscus has the form of a funnel, flattened slightly anteroposteriorly, and there is no true fundus such as is seen in the adult bladder. According to the measurements of Uteau,[178] the trigone of the contracted bladder in both sexes in the first year of life forms an equilateral triangle the sides of which are approximately 1 cm. in length. These dimensions are about two-fifths those of the adult.

The moderately distended bladder of the infant is egg-shaped with its larger end directed forward and upward. According to the measurements of Birmingham,[167] the organ when in this condition lies approximately half in the abdominal and half in the pelvic cavity. The fully distended bladder in children is almost completely an abdominal organ and may extend upward to the level of the umbilicus. Fig. 146.

The descent of the bladder after birth has been carefully studied by Disse.[168] He recognizes four stages in this process: First, a period of rapid descent extending from birth to the beginning of the fourth year; second, a period from three to nine years in which the descent is slow but continuous; third, a stage extending from nine years to puberty in which the bladder remains stationary; and fourth, a period from puberty to the end of the second decade in which the organ completes its descent.

As the bladder descends into the pelvis, the opening of the urethra is shifted farther and farther away posteriorly from the symphysis pubis. At the same time the apex of the bladder descends rapidly along the anterior abdominal wall and comes to lie, in the completely contracted bladder, at a level but little above that of the urethra. In this way the axis of the bladder is changed from the vertical to the horizontal plane of the body. This change in axis is generally completed by the end of the third or fourth year. The form of the fully expanded bladder is approximately the same in the newborn and adult.

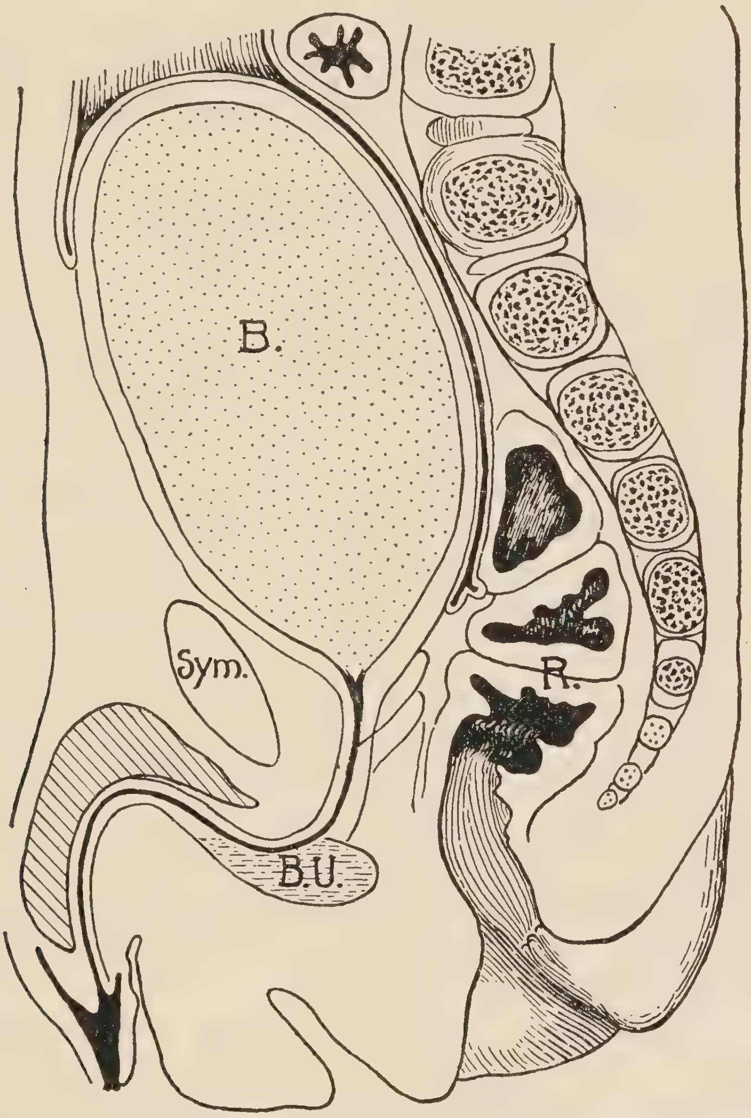

Fig. 146.—A median sagittal section of the pelvis of a male infant 9 months old with the bladder distended. B., bladder; B.U., bulbus urethræ; R., rectum; Sym., symphysis pubis. (After Symington.[14])

The capacity of the bladder at birth and in later life is extremely variable, and the available figures regarding it are probably not very valuable. Birmingham[167] injected the bladder of a newborn male in situ with a gelatin solution at a pressure of 6 to 8 cm. of water, and found the bladder contents to be 27.8 c.c. Kalaschnikoff (quoted by Gundobin[7]) found the average capacity of the bladder of the newborn, when removed from the body, to be 50 c.c. The latter author found the capacity to be more than doubled in three months and nearly quadrupled by the end of the first year.

The urachus of the infant does not differ greatly, except in length, from that of the adult. Its lumen is normally obliterated in the fourth or fifth month of fetal life, and although portions of the canal may remain in the form of cysts or diverticula of the bladder these are probably no more numerous in the newborn or child than in the adult.

THE MALE GENITAL ORGANS

The Testes (Figs. 147, 149)

The two testes with their epididymides weigh about 2 gm. at the time of birth. This weight is doubled in the first two years of life. Thereafter the weight increase is very slow, the average weight in the thirteenth or fourteenth year being about 4 gm. Between this time and the sixteenth year, *i.e.*, with the establishment of puberty, the weight of the testes and epididymides increases fivefold to 20 gm. The testes continue to increase, although in varying degrees, at least to the twenty-fifth year when they weigh 40 to 50 gm. According to Vvedenski's[193] observations, the right testis is the heavier in early infancy while in later life the left is the heavier one.

The relative weight of the testes is almost the same in the newborn and the adult. The testis in the newborn is, on the average, 10 mm. long and 5 mm. in breadth and thickness. It increases four times in length and somewhat more than four times in breadth and thickness between birth and maturity. The long axis of the testis is practically vertical in the infant, whereas it is directed forward and outward as well as upward in the adult.

Sections of the testes of the newborn show small convoluted or contorted tubules separated by a large amount of delicate connective tissue. The tubules are 60 to 80 micra in diameter and are generally solid. They are made up of small undifferentiated sustentacular cells and larger and less numerous germ cells (spermatogonia). Interstitial cells of Leydig are found in the connective tissue septa either singly or gathered in small groups. During childhood the contorted tubules slowly increase in diameter and acquire central lumina. The spermatogonia increase in number and size, and the sustentacular cells tend to gather in a definite layer at the periphery of the tubules. The connective tissue does not increase at a rate equal to that of the tubules and therefore forms less and less of the mass of the testis. With puberty the seminiferous tubules enlarge rapidly, the sustentacular cells take on their characteristic adult form, and the germ cells begin the process of maturation. The cytologic changes in the germ cells at puberty have not been studied in detail in man. The interstitial cells of Leydig are said to increase in number from birth to puberty.

Descensus Testiculorum and the Tunica Vaginalis (Figs. 147, 150)

The testes are intra-abdominal in position during the greater part of fetal life and only reach their permanent scrotal position in the eighth month. In fetuses of the latter part of the second month they are a pair of narrow elongated bodies extending from the upper lumbar region to or into the upper sacral region. The upper part of the genital mass undergoes degeneration while the lower portion remains to form the definitive testis. In the third fetal month the testes are found in the iliac fossæ. This change in position is brought about not by the active migration of the structures, but mainly by the atrophy of their cranial parts. At this time the testis possesses a mesorchium of complex and multiple origin. The caudal part of this fold extends from the lower pole of the testis to the point on the anterior abdominal wall where the inguinal canal will be formed. In the core of this fold as well as along the line of its attachment to the abdominal wall there is developed a band of fibro-muscular tissue which is known as the gubernaculum testis. This band secures its attachment in the region of the future scrotum before the definite muscular layers of the abdominal wall are differentiated. When these layers are formed they grow around this band.

The testes lie at the site of the future abdominal ring from the fourth until the seventh month of fetal life. In the meantime the abdominal wall in this region becomes greatly thickened and by a series of complex changes the caudal end of the peritoneal cavity on either side is reduced to a small diverticulum, the beginning of the processus vaginalis. The lower pole of the testis often lies just within the upper part of this sac which has, in fact, grown up around it. The processus vaginalis eventually passes through the anterior abdominal wall and, extending over the pubis, invades the scrotum which is solid at this time. In doing so the tunica passes into an interval which is already formed in the abdominal musculature. The gubernaculum testis and the tunica vaginalis both pass down into the scrotum carrying the several layers of abdominal musculature and fascia before them. The latter become the fascial investments of the testis. During the seventh month the testes, which are already partially enclosed by the upper end of the tunica vaginalis, pass down through the inguinal canal, and by the middle of the eighth month are generally attached to the fundus of the scrotum. The left testis generally descends a little in advance of the right. The chronology of the process of descent is generally quite regular and the records of a large series of cases show the testes to be in their final position in over 90 per cent. of newborn children.

Much has been written on the cause of the descent of the testes but the subject is still far from clear. As has been pointed out in the

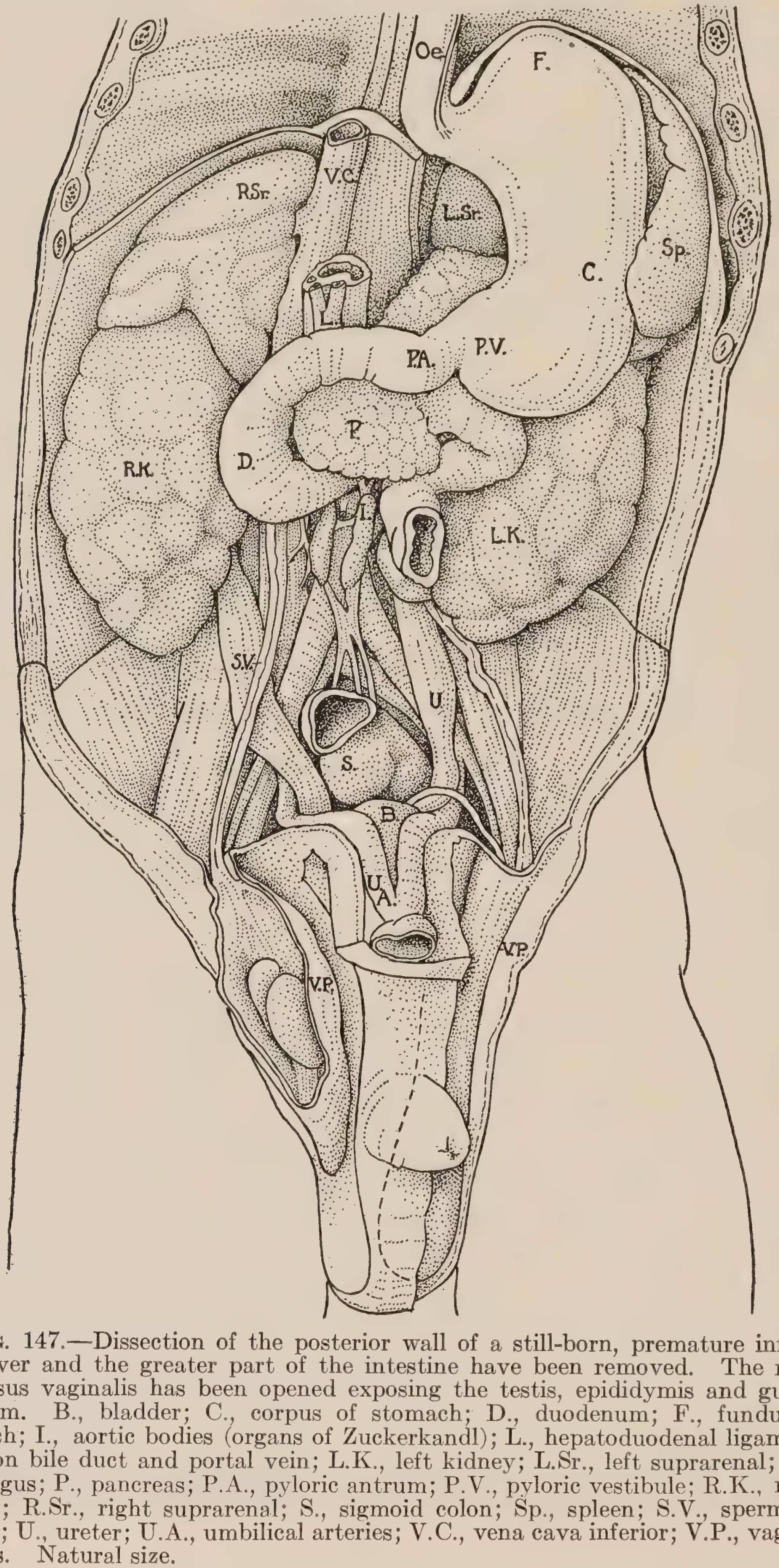

FIG. 147.—Dissection of the posterior wall of a still-born, premature infant. The liver and the greater part of the intestine have been removed. The right processus vaginalis has been opened exposing the testis, epididymis and gubernaculum. B., bladder; C., corpus of stomach; D., duodenum; F., fundus of stomach; I., aortic bodies (organs of Zuckerkandl); L., hepatoduodenal ligament, common bile duct and portal vein; L.K., left kidney; L.Sr., left suprarenal; Oe., esophagus; P., pancreas; P.A., pyloric antrum; P.V., pyloric vestibule; R.K., right kidney; R.Sr., right suprarenal; S., sigmoid colon; Sp., spleen; S.V., spermatic vessels; U., ureter; U.A., umbilical arteries; V.C., vena cava inferior; V.P., vaginal process. Natural size.

preceding paragraphs, the shifting in position of the testes within the abdominal cavity is due not to an actual descent of the organs, but at first to the degeneration of their cranial parts, and later to the conversion of a portion of the cranial part of the abdominal cavity into the tunica vaginalis. The part played by the testes themselves is entirely passive. The movement of the testes through the inguinal canal is, however, an actual descent. Among the factors suggested as causing this descent are the pressure of the rapidly growing abdominal viscera, the shortening of the gubernaculum (first through actual contraction of its muscle fibers and later by its shrinkage during atrophy), the vertical position of the inguinal canal in the fetus, and finally the "inequality of growth in the tissues."

The processus vaginalis communicates with the general peritoneal cavity above in nearly two-thirds of all children under two weeks of age, according to the extensive series of observations of Engle[182] and of Sachs.[190] After this time, however, the obliteration of the communicating canal is very rapid, more than 80 per cent. of the cases between 10 and 20 days showing partial or complete obliteration. The table of Sachs is given in summary below.

The left communication is generally obliterated some time before the right one and when both are present the left opening is almost always the smaller. This finding is in accord with the greater frequency of right inguinal hernia and with advanced descent of the left testis. Lockwood[186] described the obliterative process as taking place at two points, one near the upper and one near the lower end of the inguinal canal. This is not confirmed by the observations of Sachs who found the process beginning in the middle third of the portio funicularis, and extending upward and downward from this point.

Table 21.—The Post-natal Obliteration of the Processus Vaginalis (After Sachs[190])

Age	Number of cases	Condition of processus vaginalis in percentages			
		Obliterated	Open above	Entirely open	Total of cases of incomplete or total lack of obliteration
0 to 10 days.....	27	20	19	61	80
10 to 20 days....	40	50	32	18	50
20 to 30 days....	15	47	23	30	53
30 to 60 days....	25	36	34	30	64
60 to 90 days....	22	36	39	25	64
90 to 120 days...	13	65	16	19	35
120 to 335 days..	13	69	27	4	31

THE PROSTATE (Figs. 146, 148)

In its growth, the prostate follows closely the history of the structures of the male genital tract. Arising in the latter part of the third fetal month, the gland grows slowly for a period; but one or two months before birth it begins to increase at a rapid rate and between this time and birth its weight is doubled. From birth until a short time before puberty, the prostate grows very slowly and the gland hardly doubles its weight in the first decade of post-natal life. From puberty or shortly before puberty until the middle of the third decade, the prostate again grows rapidly, particularly before the twentieth year.

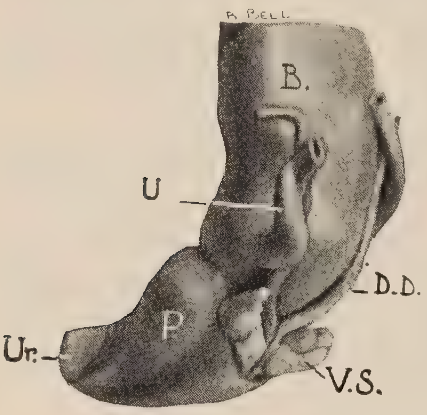

FIG. 148.—Base of the bladder and the prostate gland of a full-term newborn child. B., bladder; D.D., ductus deferens; P., prostate; U., ureter; Ur., urethra; V.S., seminal vesicles.

The dimensional changes of the prostate are similar to those of weight; during childhood they are augmented very slowly but during and after puberty very rapidly. Although subject to great individual variation it may be said that the length, breadth, and thickness are usually tripled between birth and maturity. The chestnut form so often assigned to the adult prostate is less noticeable in childhood; at this time the organ is more conical in shape and the lateral borders, which are prominent in the adult gland are rounded and merge into the surfaces.

The prostatic urethra is approximately 1 cm. in length in the newborn; it is two and one-half times longer in the adult. Apparently most of the length increase takes place after puberty.

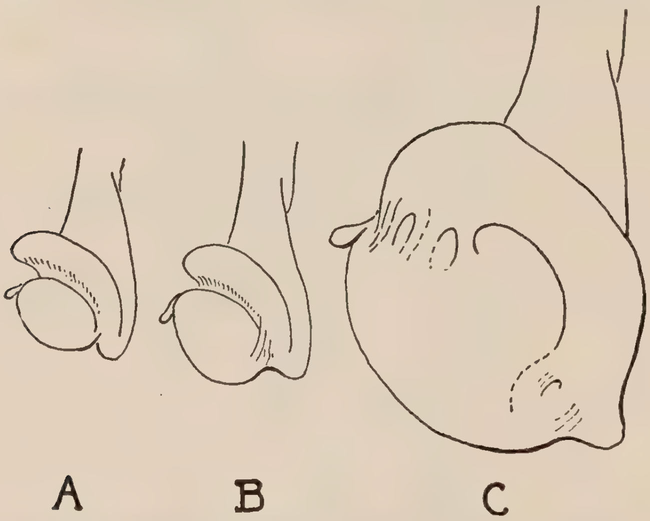

FIG. 149.—Three drawings illustrating the growth of the testis and epididymis and the postnatal changes in the digital fossa. A., newborn. B., child of two years. C., adult. All enlarged one and one-half times. (After Poirier, Rev. de Chir., X.)

The finer structure of the prostate in childhood has been recently investigated by Lowsley[187, 188] and Hada,[185] and the following outline is based mainly on the accounts of these authors. The total adult number of prostatic tubules is already present at the time of birth and the post-natal increase in glandular tissue is brought about by the enlargement of these elements. In the newborn the tubules have the form of elongated and irregular sacs which often end in dilations and which may have lateral outpouchings. The terminal portions of the glands may be solid at birth, but they acquire lumina in early infancy. The tubules grow very slowly during childhood but at puberty they increase greatly in caliber and give off many lateral branches, particularly from their distal portions. Lowsley estimates that the glandular tissue forms one-third of the prostate in fetuses and newborn children, and one-fourth of the prostate after puberty. As in later life, the epithelium lining the tubules is extremely variable in height. Lowsley has also investigated the post-natal history of the small groups of glands which are associated with but are not, properly speaking, part of the prostate (the subcervical glands of Albarran, the subtrigonal glands and the apical glands). He finds that, unlike the true prostatic glands, they increase in number from birth to puberty.

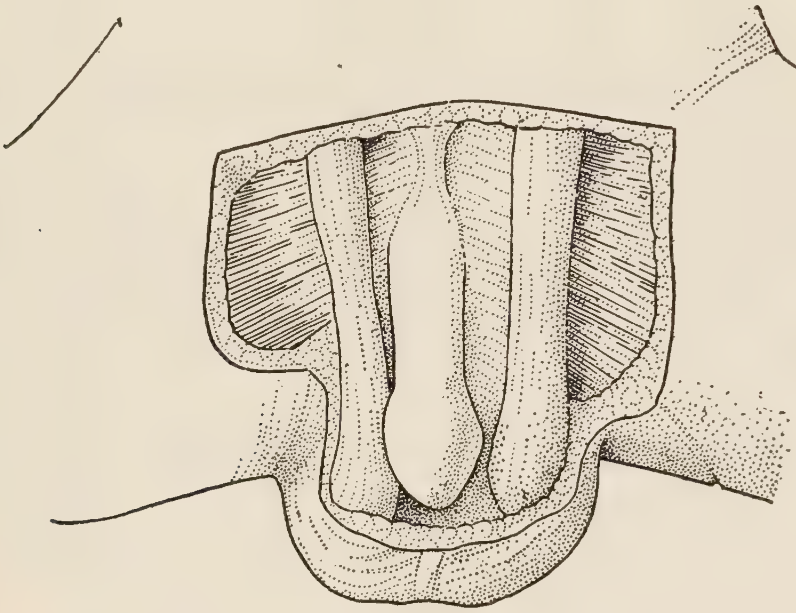

FIG. 150.—Superficial dissection of the external genitalia of a newborn male child. Natural size. (After Credé-Hoerder.[181])

The muscular tissue of the prostate is weakly developed in children, but increases rapidly along with the rest of the gland at puberty. Elastic tissue is confined mainly to the center of the gland until puberty when it also is greatly increased.

Schlachta[191] has described a natal secretion of the prostate which is present in the late fetus and which disappears shortly after birth. True prostatic concretions are not found in the prostates of children although masses of a colloid eosinophile substance sometimes occur in the lumina of the prostatic tubules.

THE URETHRA AND PENIS (Fig. 150)

The male urethra is 5 or 6 cm. long in the newborn. The details of its later growth are shown in Table 22 which is a summary of the measurements made by Zwineff (quoted by Gundobin[7]). As will be seen from this table, the urethra practically triples its length between birth and maturity and the rate of increase is a fairly regular one except for a slight acceleration at puberty. Most of the growth takes place in the cavernous urethra.

The structure of the urethra and penis is quite similar in the infant and adult. Urethral glands and lacunæ are already present at the time of birth although they increase both in size and number during childhood. The erectile tissue of the infant differs from that of the adult in the weaker development of the smooth muscle bundles and scarcity of elastic fibers.

During the greater part of fetal life the epithelium covering the glans penis and that lining the inner surface of the prepuce are fused together in a single plate. The separation of the prepuce from the glans begins as early as the fifth month of fetal life but is almost always incomplete at birth and may remain so for some time thereafter.

TABLE 22.—THE LENGTH OF THE MALE URETHRA IN CHILDHOOD (Based upon the Data of Zwineff and Waldeyer)

Age	Number of cases	Length of urethra (centimeters)			
		Total	Pars cavernosa	Pars membran.	Pars prostat.
Newborn	..	5.6			
1 month	4	6.2	4.6	0.8	0.8
1 year	2	6.7	5.25	0.65	0.8
2 years	4	7.6	5.3	1.0	1.3
3 years	6	8.1	6.2	0.9	1.0
5 to 6 years	6	9.4	7.4	0.9	1.1
8 to 10 years	8	10.4	8.2	1.0	1.2
11 to 12 years	4	11.1	8.9	1.0	1.2
13 to 14 years	4	11.9	9.2	1.1	1.6
15 to 16 years	4	15.7	12.2	1.5	2.0
Adult	..	18–20			

THE SCROTUM AND SPERMATIC CORD (Figs. 106, 150)

The scrotum of the infant is relatively short and broad and the distinction between the fundus and neck of the sac is not noticeable until a year or more after birth. Both the peripheral walls and the septum are relatively much thicker in the infant than in the adult.

The spermatic cord is also relatively thicker in the infant than in later life. Its circumference in the suckling is almost as great as that at puberty, and more than half that of the average adult. In the newborn and suckling the cord passes almost vertically from the base of the scrotum through the inguinal canal. The cremaster muscle is highly developed in the infant.

THE FEMALE GENITAL ORGANS

THE OVARIES (Figs. 151, 152, 153, 155)

During the latter part of fetal life the ovaries grow very rapidly. Their average weight in the newborn is about 0.3 gm. The rapid growth of the ovaries is continued in early post-natal life, and the structures double their weight in the first six months. The birth weight of the ovaries is tripled by the end of the third year, and increased seven- or eight-fold by the end of the tenth. Such statistics as we have, indicate that the weight of the ovaries is nearly doubled

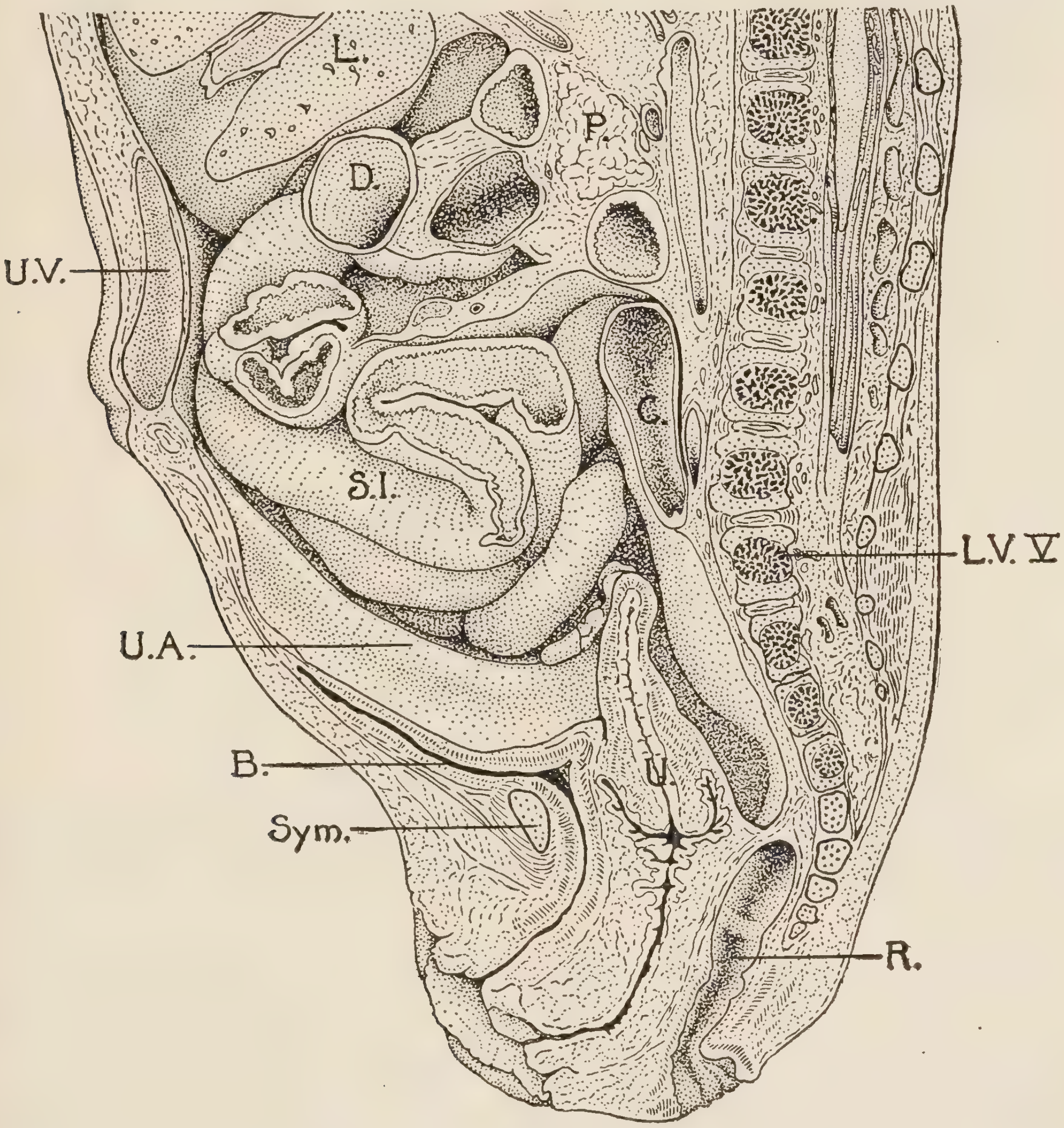

FIG. 151.—Median sagittal section of the pelvis of a full-term, newborn female child; B., bladder; C., colon; D., duodenum; L., liver; L.V.V., fifth lumbar vertebra; P., pancreas; R., rectum; S.I., small intestine; U., uterus; U.A., umbilical artery; U.V., umbilical vein. Natural size.

between 12 and 15 years, and the total weight increase from birth to maturity is about sixteen fold. The ovaries show great individual variation in weight throughout childhood because of the fluctuation in the development of the vesicular or Graafian follicles during this period. The variation in the relative weight of the ovaries during childhood is so great that no general statements can be safely made regarding it.

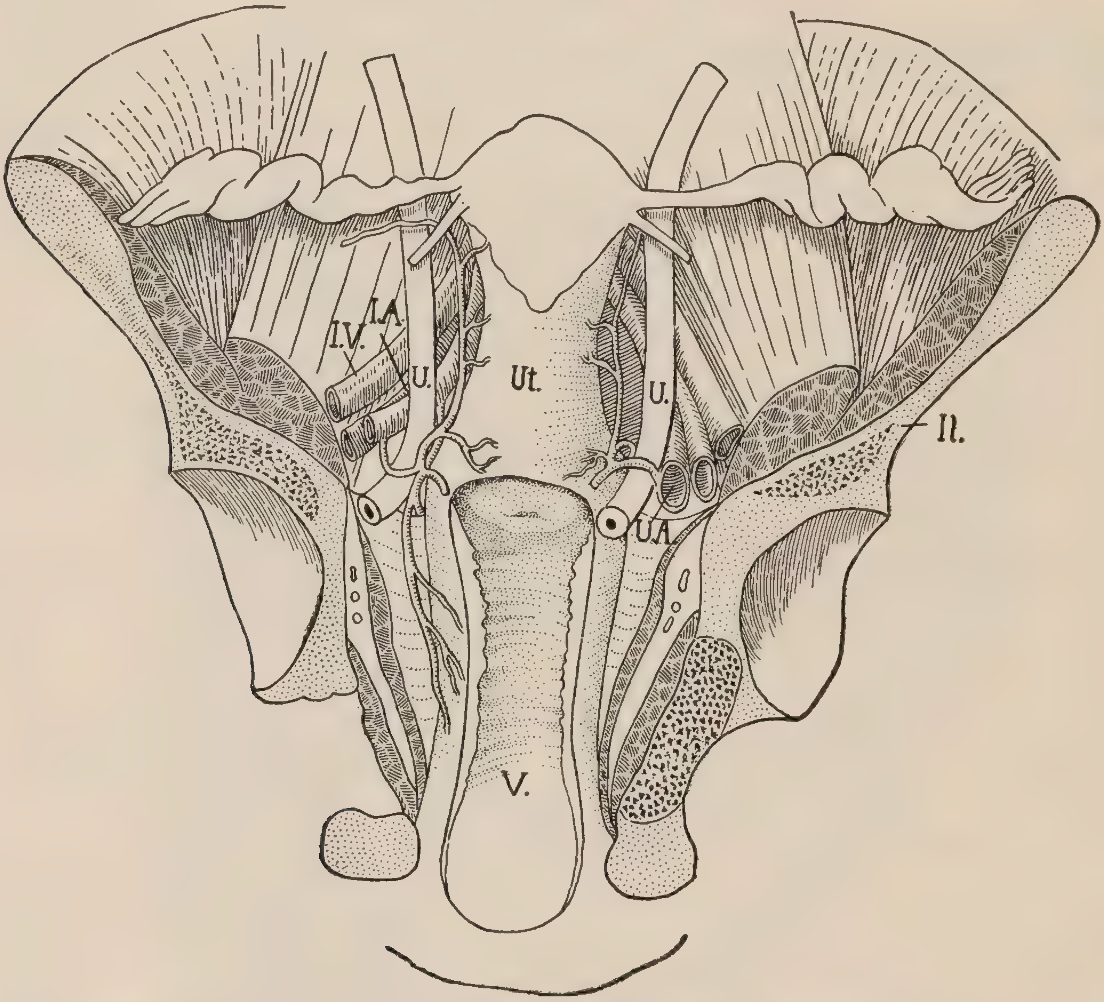

Fig. 152.—Semidiagrammatic frontal section of the pelvis of a newborn female child. I.A., external iliac artery; Il., ilium; I.V., external iliac vein; U., ureter; U.A., umbilical artery; Ut., uterus; V., vagina. (After Fredet, Thèse, Paris, 1899.)

The form of the ovaries is quite variable in early childhood. At birth they are from 15 to 30 mm. in length and 4 to 8 mm. in breadth. They are generally triangular in cross section in their central portions, but are rounded at their extremities. With the great development of vesicular follicles in the first two or three years of life the ovarian surfaces become rounded and the furrows which often indent them at birth disappear.

The ovaries, like the testes, change from an abdominal to a pelvic position during fetal life. According to the observations of Wendler,[220] they lie in the middle of the lumbar region at the beginning of the third fetal month, at the upper margin of the iliac crests at the beginning of the fourth month, and well in the iliac fossæ by the middle of the fifth month. In the newborn they are generally found at the lower margin of the iliac fossæ. Their passage over the iliopectinal line into the fossa ovarica immediately below it generally takes place in early childhood; but it may be accomplished before birth, or be delayed until puberty, or sometimes may not occur at all. The long axis of the ovary is in the sagittal plane of the body in the young fetus, but as the descent takes place the upper pole is rotated outward and the axis comes to lie in the transverse plane. As the ovary reaches its permanent position in the fossa ovarica above the larger pelvic vessels and posterior to the broad ligament, the lateral or superior pole is shifted backward and the long axis of the organ again falls in the sagittal plane of the body.

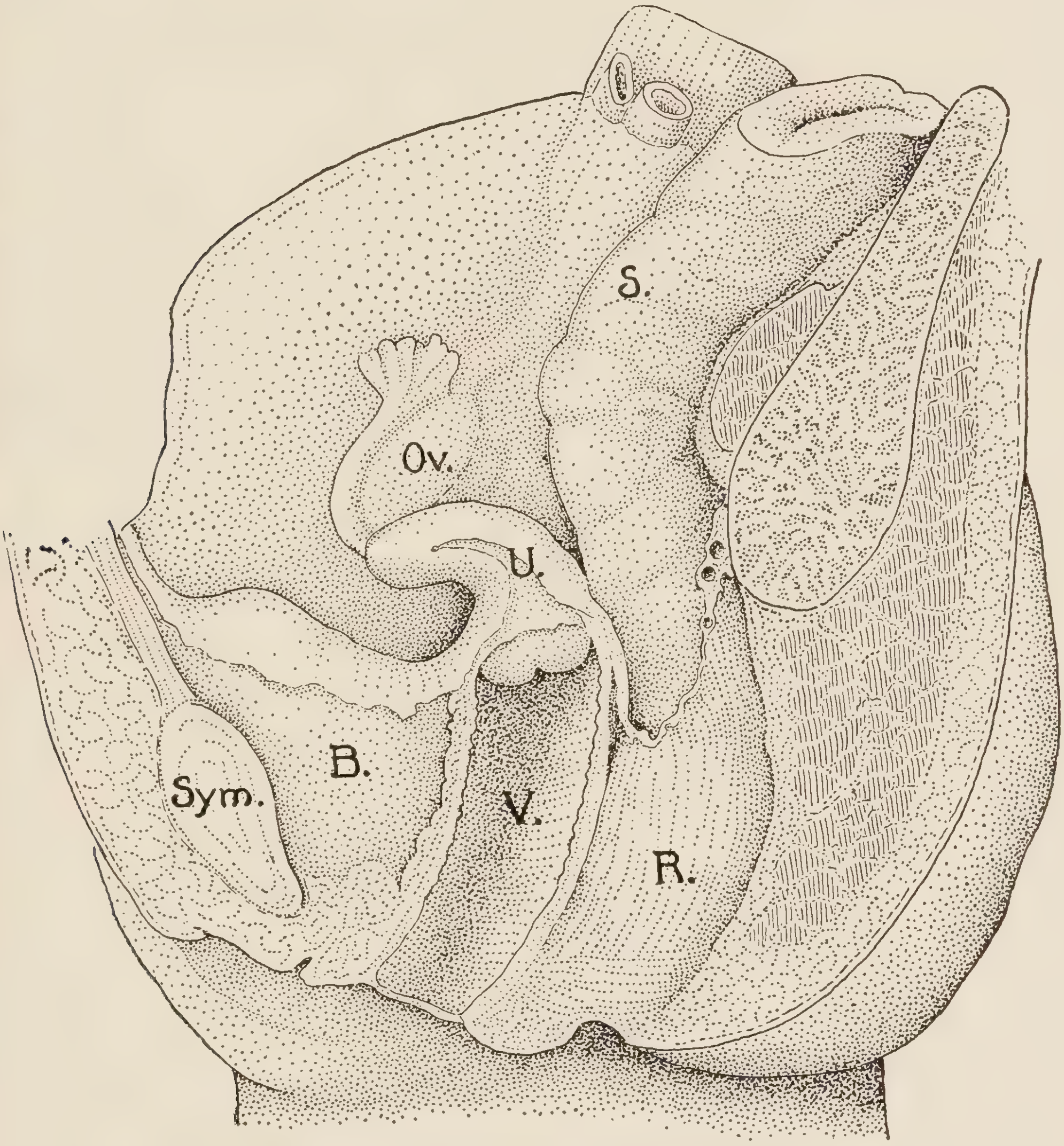

Fig. 153.—Dissection of the pelvis of a girl ten years old. B., bladder; Ov., ovary; R., rectum; S., sigmoid colon; Sym., symphysis pubis; U., uterus; V., vagina. (After Boullard.[199])

Associated with the descent of the ovaries is the canal or diverticulum of Nuck which is the homolog of the processus vaginalis of the male. This diverticulum is open in about 20 per cent. of female children under one year of age. The right diverticulum is open more often than the left, as is the case with the processus vaginalis in the male.

The cortex of the ovary of the newborn is sharply marked off from the medulla and forms relatively a much larger part of the organ than in later life. It is composed mainly of primordial follicles which are separated by a very small amount of delicate connective tissue. Generally 20 to 25 rows of follicles can be counted between the inner and outer margins of the cortex. The number of follicles at birth has been estimated as high as 400,000 or even 800,000, but these figures are undoubtedly far too large and more modern calculations have put the number at from 40,000 to 80,000. During childhood and adolescence there is a great reduction in the number of ova but the time of this decrease apparently varies greatly in different individulas. Hansemann,[205] estimated the number of ova in a series of children's ovaries as follows: Six and one-half months, 30,000; two years, 48,000; eight years, 26,000; ten years, 21,000; and fourteen years 16,000. The number of ova in the eighteenth year has been calculated at 5,000 to 7,000. Thus there is a decrease of approximately 90 per cent. in the number of ova between birth and full sexual maturity.

Graafian, or vesicular, follicles are found in the ovary as early as the seventh month of fetal life and are often present in the ovaries of newborn children. During the first and second years they are formed in large numbers from the primary follicles, and by the end of this period they occupy the greater part of the ovarian cortex. The fate of the Graafian follicles formed in childhood has been the subject of a number of investigations. Undoubtedly the great majority undergo atresia before reaching complete development. However, corpora lutea have been observed, although rarely, in the ovaries of newborn and older children and the possibility of occasional ovulations is not excluded. Probably all the egg cells of the newborn child are oocytes of the first order and if this is the case there can be no production of new ova after birth. The presence of two or more ova in a single primordial or Graafian follicle is not unusual in children. Interstitial cells which lie imbedded in the stroma of the ovary and are not associated with the ovarian follicles are numerous in the fetus and apparently reach their highest development at or before birth. Interstitial cells derived from the theka cells of atretic ovarian follicles appear shortly after birth and increase in number until puberty (Fraenkel[204]).

Space will not permit a discussion of the vascular changes in the ovary during childhood. This subject is described in detail in an excellent paper by Clark.[201]

THE UTERUS (Figs. 151, 152, 153, 154)

The uterus at the time of birth varies in length from 25 to 50 mm., the average of a series of 120 cases being 35 mm. Its weight is between 3 and 4 gm. The cervix forms two-thirds or more of the length of the uterus in the newborn, and its walls are much thicker than those of the corpus. There is no definite isthmus present at birth.

During the first few weeks of post-natal life the uterus undergoes a marked involution, in which its length decreases about one-third and its weight over one-half. This involution is due mainly to an atrophy of the uterine muscle. Although the organ shows some growth at about five or six years, its natal dimensions are rarely regained before 11 years. Usually in the twelfth year, however, a period of very rapid growth sets in and by 16 or 15 years the organ has usually attained nearly its adult weight and dimensions. Until this period of rapid growth the infantile relations of the corpus and cervix remain practically unchanged, but during this period the corpus increases rapidly in all dimensions while the cervix remains stationary. By this process of unequal growth the adult proportions are attained by the time of puberty. The isthmian segment of the uterus can hardly be distinguished during the first years of life. It is formed from the upper part of the cervix and increases but little in length after its appearance.

The uterine cavity in the child is a narrow slit-like cleft, flattened anteroposteriorly, and widest at its lateral margins. It is indented on its anterior and posterior margins by a series of folds known as the plicæ plamatæ or arbor vitæ. These generally consist, on either side, of a central longitudinal ridge from which numerous side ribs pass off upward and backward. The plicæ palmatæ usually disappear, in part at least, in the prepubertal growth period.

The thickness of the uterine mucosa in childhood varies from 0.5 to 1.5 mm. This variation shows no relation to the age of the individual. The lining epithelium consists of a single layer of cuboidal cells. The presence of cilia on the uterine epithelium in childhood has been a matter of considerable dispute but it seems that as a rule they are absent until the time of puberty. The development of the uterine glands in the child has never been thoroughly investigated, and seems to be an extremely variable process. Small mucous crypts and simple tubular glands are often seen at the time of birth opening into the bottoms of the folds which separate the plicæ palmatæ; these increase in number throughout childhood although at an extremely variable rate and without much change in form, and branched glands are rare in the uterus in childhood. The cervical glands are often represented at birth by small crypts but in the later periods of childhood they develop more slowly than the glands of the corpus. We have little knowledge of the numerous changes which must take place in the uterine glands at puberty. Baumgartner, Nelson and Dock (Am. Jour. Anat., xxvii, (1920) found a rapid growth and division of the glands at 14 years.

In the newborn child and the young infant, the uterus lies wedged in the narrow cavity of the lesser pelvis between the base of the bladder and the rectum. Consequently its position depends in a large measure on the condition of these organs. At birth the bladder contains but a small amount of fluid while the rectum is distended with meconium; as a result the uterus is pressed forward and is practically always more or less anteverted. Later in infancy, as the bladder descends into the pelvic cavity, the uterus may be both anteverted and anteflexed. With the bladder distended the uterus may be vertical or even retroflexed. The uterus is generally displaced a little to the right of the median line in the newborn, and its upper third generally lies above the plane of the superior aperture of the lesser pelvis.

THE VAGINA, EXTERNAL GENITALIA AND URETHRA (Figs. 151, 152, 153)

The vagina is from 2.5 to 3.5 cm. in length in the newborn (Ballantyne[1]). As in later life, the posterior wall is distinctly longer than the anterior one. The organ grows very slowly in childhood and rapidly in the prepubertal period, but there is apparently great individual variation in the rate of longitudinal growth. Before the menarche there is a marked increase in the number of blood vessels and the amount of elastic tissue in the vaginal walls. Post-natal involutional changes, such as occur in the uterus, have not been found in the vagina.

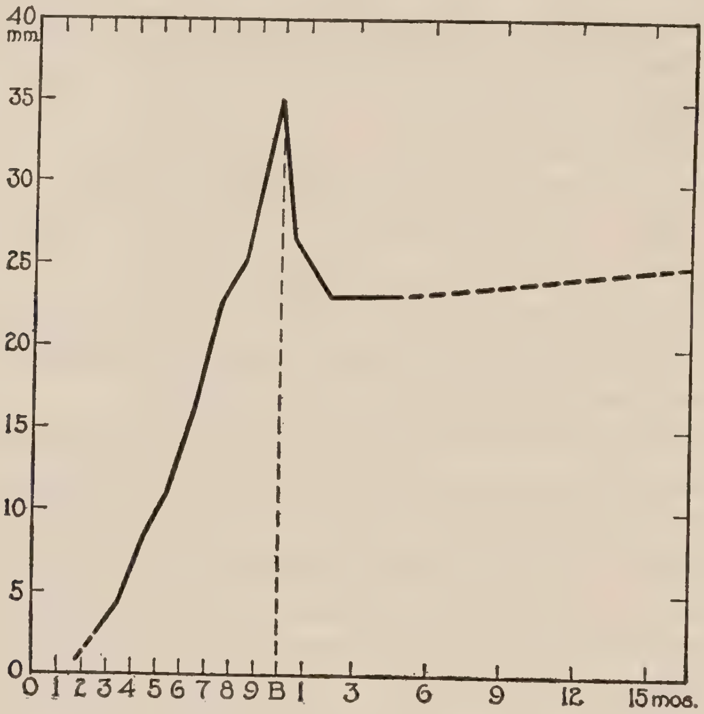

FIG. 154.—A graph illustrating the changes in the total length of the uterus in fetal and early postnatal life. B, on the base line, indicates birth. (Based upon 385 observations.)

The hymen in the infant generally appears as a thickened lip which surrounds the lower orifice of the vagina and projects somewhat into the vestibule. It is relatively thicker and more vascular than in later life and is more superficially placed. During early childhood it gradually assumes a deeper position and takes on a diaphragmatic form.

The labia majora and minora are relatively large in infancy. The former are generally united below by a very definite posterior labial commissure. The glands of the lateral sides of the labia minor are first developed at about three years; those of the medial side at eight or nine years.

The urethra is about 1.5 cm. long in infancy and 3.5 cm. long at puberty. The diameter, as measured with the sound, is about 4 mm. in infancy and 8 to 10 mm. at puberty (Gundobin[7]). A longitudinal ridge running from the external orifice of the urethra, or the superior margin of the hymen to the base of the clitoris, is generally quite prominent in childhood.

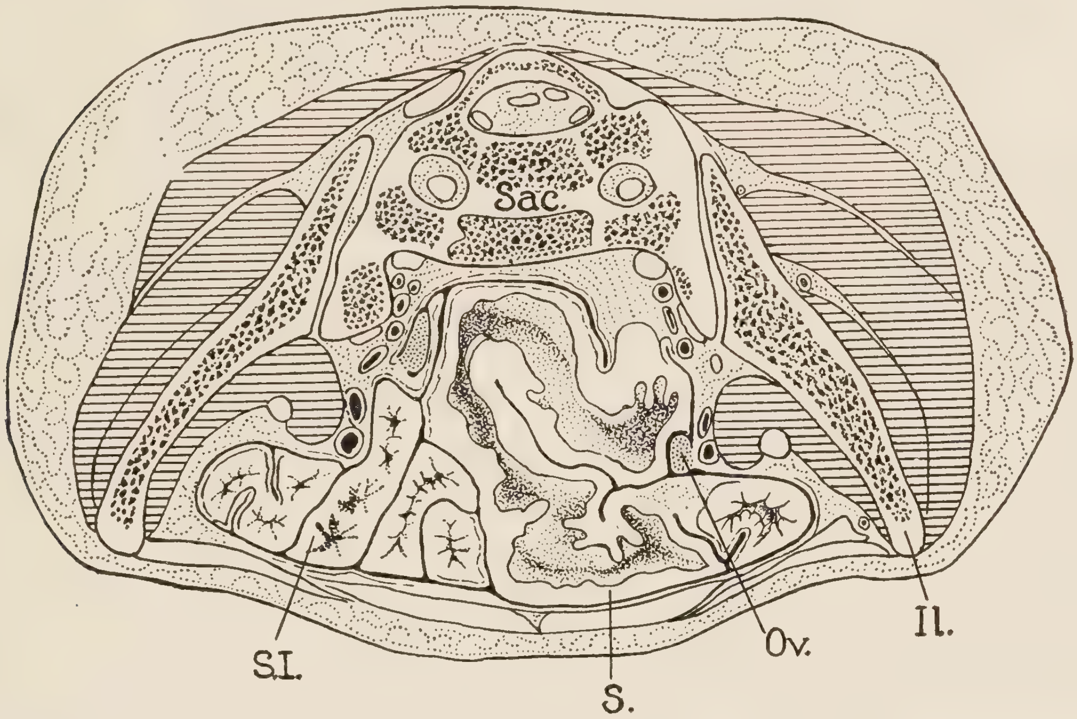

Fig. 155.—Transverse section of the pelvis of a girl 4 years old. Il., ilium; Ov., ovary; S., sigmoid colon; Sac., sacrum; S.I., small intestine. (After Dwight.[4])

The Mammary Gland

At birth and in infancy the center of the areola, which corresponds to the nipple in later years, generally lies at the level of the fourth intercostal space or the fourth rib. The average distance between the areolar centers in the first year is 9.5 cm. according to the observations of von Stark.[300] With the growth of the thorax the nipples gradually move farther apart; in the sixth year the average distance between them is about 12 cm. and at puberty about 16 cm. The lateral shifting of the nipples proceeds a little more rapidly than the increase in the transverse diameter of the thorax, so that the mammary line in maturity and later childhood is both relatively and absolutely farther from the median plane of the body than in infancy.

In the latter part of fetal life the gland is composed of 15 or 20 narrow tubules which branch several times near their termination. The terminal or secretory parts of these tubules are lined, as a rule, by a double layer of columnar cells; while the portions which represent the lactiferous ducts are lined by three or four layers of cells, although there is no sharp line of demarcation between the ducts and secretory portions of the tubules. The epithelial elements of the gland are supported by a delicate connective tissue which contains some wandering cells.

Within a few days after birth the glands begin the active production of their natal secretion or witches' milk. Witches' milk is formed in practically the same way as is the milk of adult lactation (Brouha[200]). The mammary glands become swollen and project from the general level of the thorax. The alveoli are greatly distended and the cells lining them rapidly elaborate fat-droplets which escape into the lumina of the alveoli. The connective tissue which separates the alveoli is relatively reduced and is infiltrated with lymphocytes and other wandering cells some of which pass into the lumina of the glands. As the milk is not removed from the gland the lactiferous ducts become greatly distended. The secretion of witches' milk usually ceases two or threee weeks after birth, but cellular débris and milk-corpuscles are found in the lumina of the ducts for some time thereafter. The ducts are not reduced to their natal size until six months or more after birth. According to the observations of Herz,[207] the glands are not larger in females than in males during the period of natal secretion.

The finer structure of the mammary glands during the remainder of childhood is very incompletely known, but there seems to be little change between infancy and the latter years of childhood. Before puberty the mammæ grow considerably in size, but this growth is due mainly to an increase in the amount of the interstitial connective tissue and fat. At puberty the lactiferous ducts become larger and numerous epithelial sprouts grow out from them. The elastic tissue of the gland also becomes more abundant and the vascularity increases. The male gland does not undergo these changes although there is an increase in its blood supply at puberty.

The nipple generally begins to grow above the surface of the areola in the first year of life. It is not completely formed until puberty.

THE DUCTLESS GLANDS

The Thyroid Gland (Fig. 177)

The thyroid gland generally weighs from 1.5 to 2.5 gm. in the full-term newborn. The higher averages of 4 gm. or more, which are sometimes cited in the older literature, are based in practically all instances on material collected from or near the Alpine districts of Europe where congenital hyperthyroidism is common. The weight of the thyroid at birth is about 0.06 per cent. of the body weight. The weight of the thyroid in childhood is very variable and reliable statistics on the subject are scanty. While there are a number of records of thyroid weights in children, there are comparatively few in which the material has been proven normal by histologic examination and without this proof their value is extremely doubtful. In general, the acceptable cases on record indicate that the weight of the gland increases to about 10 gm. by the tenth year, and to about 15 gm. at puberty.

The dimensions of the thyroid in childhood are as variable as the weight. Weiben found that in the first two years of life the length of each lobe was from 2 to 3 cm., the breadth from 1 to 1.5 cm., and the thickness from 0.8 to 1.2 cm. There is no particular relation between the dimensions and the age of the gland during this period. All of these dimensions are about one-half those of the mature gland. One gains the impression from dissections of the thyroid region in infants that the gland is larger in proportion to the larynx than in later life and that it covers a larger portion of the thyroid cartilage.

Our information concerning the finer structure of the thyroid gland at birth and in early infancy is still in a very confused state. Norris[243] has shown that the epithelial anlagen of the gland first breaks up into a number of plates and bands, and that follicles are formed from these structures. Follicle formation begins in the early part of the second fetal month and by the middle of the fourth month all of the original plates and bands are converted into these structures. Thereafter new follicles can be produced only by the budding or the division of older ones. Norris finds that the increase in the number of follicles up to the end of the fourth fetal month is very rapid; but that the subsequent growth of the gland, during the greater part of the remainder of fetal life at least, is due rather to the growth in the size of the follicles than to the increase in their number. Very little is known about the growth of the follicles in post-natal life. The formation of new follicles after birth by the processes of budding and division has been described by Isenschmidt[236] and Hesselberg[235] and others. Gleim,[233] who measured the follicles in a series of children from 10 days to 7 years of age, found no definite evidence of any regular increase in their size after birth.

Colloid appears in the thyroid follicles about the end of the third fetal month. It is preceded by a precolloidal material which appears granular in microscopic sections. A number of observers have described the disappearance of the colloid in the latter part of fetal life and the desquamation of the lining epithelium of the follicle into its cavity. These phenomena are not constant ones and their interpretation is not clear. Possibly they represent a pathologic process or post-mortem degeneration.

Parski[244] and Forsyth[232] claim that accessory thyroid masses are not as numerous in infants as in adults.

THE PARATHYROID GLANDS

The number of parathyroid glands is probably as variable in the child as in the adult. Forsyth,[232] who carefully examined a large series of cases, concludes that the number of parathyroids is much higher in early life than in maturity. He found an average of four parathyroids per thyroid lobe in the first year of life, 3.5 between one and five years, 1.5 in the second, and 0.7 in the third decade. Whether all the bodies which Forsyth observed in infants were true parathyroids seems, to the writer, open to question.

The dimensions of the glands are as variable as their number. In early childhood they are generally between 3.0 and 5.5 mm. long although some are microscopic in size.

At birth the glands are made up of compact masses of clear epithelial cells separated by delicate connective tissue. Faint eosinophilic granulation can be made out in some of these cells during infancy but this is subject to great variation, and well-marked eosinophilic cells are not commonly seen until about ten years Lipoid droplets appear in the epithelial cells after birth and gradually become more numerous. Colloid has been observed in the parathyroids in infancy.

MINOR EPITHELIAL MASSES OF THE CERVICAL REGION

Recently several investigators have noted the presence of numerous small epithelial masses, presumably of an endocrine nature, in the neighborhood of the thymus and thyroid, in infancy. These structures have been described under various titles, among others as the juxtathymic bodies, the para-parathyroid-thymic bodies, and the glandulæ insularis cervicalis. It is probable, however, that they all belong in a single category. Pepere[246] has published the most complete description of these masses. They are of small size—a few millimeters in diameter at most—and are found scattered around the thymus and the thyroid gland, and in the connective tissue of the anterior part of the neck. Their finer structure is quite like that of the adult parathyroid glands but differs considerably from that of the infantile parathyroids. They disappear about the end of the first period of infancy.

Whether these masses are, in fact, discrete organs, deserving a separate nomenclature, is, in the opinion of the writer, unsettled. It is very probable that they have been confused with the parathyroid glands in the past. This circumstance may account for the large number of parathyroids which some writers have found in infants and also for the great variation in the finer structure in the parathyroids of childhood which has been reported so often.

THE SUPRARENAL GLANDS (Figs. 127, 128, 129, 132, 143, 147, 156)

The relative size of the suprarenals at birth is very great. They form approximately 0.2 per cent. of the entire body-weight in the average full-term newborn as compared with 0.01 per cent. in the average adult.

The average actual weight of the two glands at birth is about 8 gm. Although the weight of the suprarenals in the newborn may vary from 2 to 16 gm., these cases of extreme variation are not common. In a series of one hundred pairs of glands of full-term newborn children, the writer found the weight to be between 6 and 9 gm. in about one-half of the cases, between 9 and 16 gm. in about one-third, and between 2 and 6 gm. in about one-sixth. As in the adult the left gland is generally heavier than the right.

The data on the post-natal weight changes in the suprarenals are rather scanty—the three most extensive series of observations being those of Scheel,[249] Blymenau[225] and Starke and Wegrzynowski.[250] Averaging all available figures it is found that the suprarenals undergo a distinct post-natal decrease in weight, dropping from an average for both glands of about 8 gm. at birth to about 5 gm. in the first fortnight and to 4.36 gm. in the period between 14 days and three months after birth. Following this initial loss the structures increase in weight very slowly but it is probable that the initial weight is not regained until about puberty. The average weight in the third decade is about 15 gm. or a little less than twice the birth weight. There seems to be no constant sex difference in the weight of the suprarenals in childhood although the available figures indicate that in early maturity the bodies are heavier in females than in males.

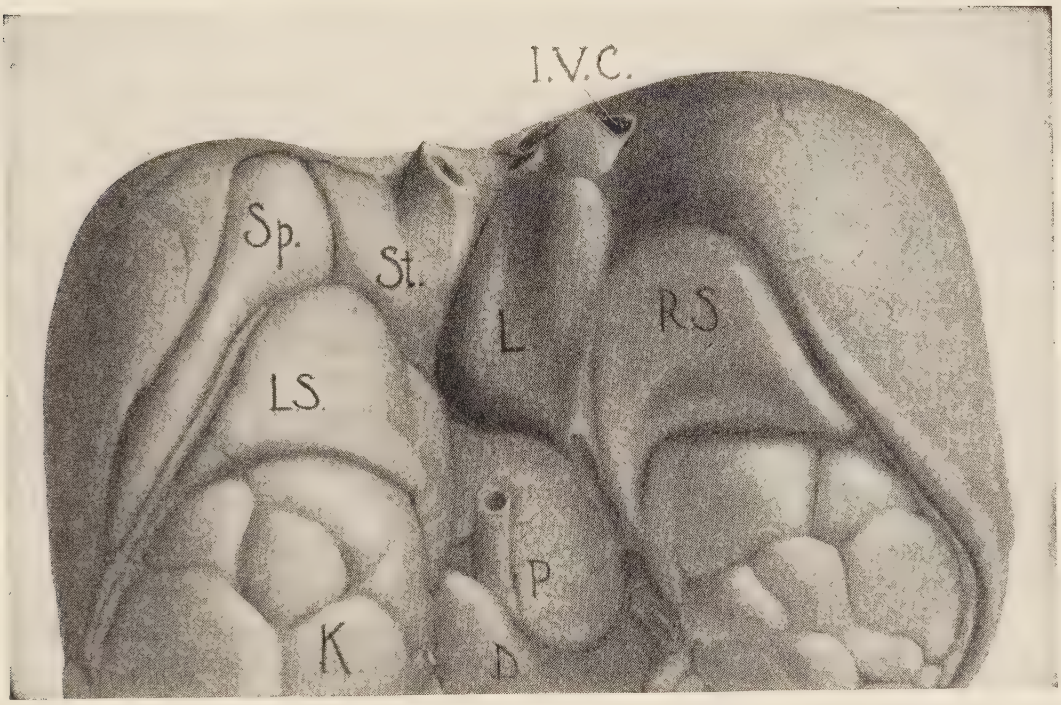

Fig. 156.—Posterior view of the suprarenals and associated viscera in a full-term newborn child. D., duodenum; I.V.C., vena cava inferior; K., left kidney; L., caudate lobe of liver; L.S., left suprarenal; P., pancreas; R.S., right suprarenal; Sp., spleen; St., stomach. Natural size.

At birth the suprarenals are generally from 2 to 2.5 cm. in length, 2.5 to 3.5 cm. in breadth and 0.8 to 1 cm. in thickness. According to the observations of Luna[241] the length and breadth remain almost unchanged in early childhood while the thickness is somewhat diminished. In the adult the length is generally from 2.5 to 3 cm., the breadth from 4 to 5 cm., and the thickness 1 cm. or a little less The furrows on the surfaces of the glands are particularly well marked at birth. At this time their margins are widely separated and rounded while in the adult they are almost in contact.

The finer structure of the suprarenal at birth is quite different from that of the adult gland. The cortex is relatively much thicker than in later life and is divided into two zones. The outer, occupying the position of the zona glomerulosa of the adult, is quite thin. It is made up of cells which have much the structure of the adult cortex cells and which are said to contain lipoid droplets. The inner layer, which occupies the position of the zona fasciculata and zona reticularis of the adult is much thicker. It is composed of larger cells arranged in columns. These cells are said to contain no lipoid. The cortex is hyperemic at birth. No pigment is found in the cortical cells in early post-natal life.

The medulla is relatively small at birth. The chromaffin cells are present but not numerous. They are arranged in anastomosing columns one cell in width. Ganglion cells are present at birth. The vascular supply is particularly rich at this time (Blymenau[225]).

The connective tissue framework of the gland is weakly developed and the elastic fibers in particular are scanty. Collections of lymphocytes along the walls of the larger vessels have been reported.

A remarkable series of changes take place in the cortex of the suprarenal during infancy. These changes were first described, I believe, by Starkel and Wegrzynowski.[250] They were reported independently by Thomas[254] a little later, and by Armour and Elliott,[224] and have been confirmed by a number of investigators since. Following the hyperemia of the cortex the large inner layer of this portion of the organ undergoes involution. The nuclei of the inner cortical cells shrink, the cells show fatty degeneration, and the columns are broken up into irregular masses. The supporting connective tissue becomes flattened into a fibrous zone around the periphery of the medulla of the gland. This involution of the inner zone of the cortex begins immediately after birth and, according to the studies of Lewis and Pappenheimer,[239] is completed by the end of the second week. The outer zone of the cortex is not affected and all of the cortex of the adult gland is formed from this portion. The regeneration of the cortex does not take place until after the first three years of life.

The topography of the suprarenals at birth is quite different from that of later life. The left suprarenal is in contact with the superior margin and the upper part of the anterior surface of the left kidney, and with the spleen, the stomach, and the body of the pancreas. In many cases the medial margin of the left suprarenal may come in contact with the liver just above the lesser curvature of the stomach. The anterior surface of the right suprarenal is in contact with the anterior surface of the right kidney, and with a large part of the inferior surface of the right lobe of the liver just lateral to the fissure for the inferior vena cava. The relations of the newborn shift rapidly to those of the adult during the first few years of life but the details of the process are not known.

Accessory Masses of Suprarenal Cortex.—Accessory masses of suprarenal cortex are very common in children. They are found both in the retroperitoneal tissue and associated with the genital organs. The retroperitoneal masses are generally found imbedded in the capsule of the suprarenal glands or lie close to these organs; but occasionally masses may be found elsewhere such as in the capsule of the kidney, the adventitia of the aorta, or the loose subperitoneal connective tissue. Their size is extremely variable; at times the suprarenals may be sprinkled with small cortical masses which are just visible to the naked eye, in other instances the bodies may be several millimeters in diameter. In male infants accessory cortical masses are commonly found in the tail of the epididymis or along the first part of the ductus deferens. These structures have been studied in detail by Wiesel.[257] He found them present in about two-thirds of all the newborn children he examined. They may occur on one or both sides of the body but are commonest on the right side only. No bodies were found in children over one year old although masses which he regarded as involuting cortical tissue were found in the epididymi of older children. Accessory masses in female infants are found in the broad ligament of the uterus for a variable period after birth (Marchand[242]).

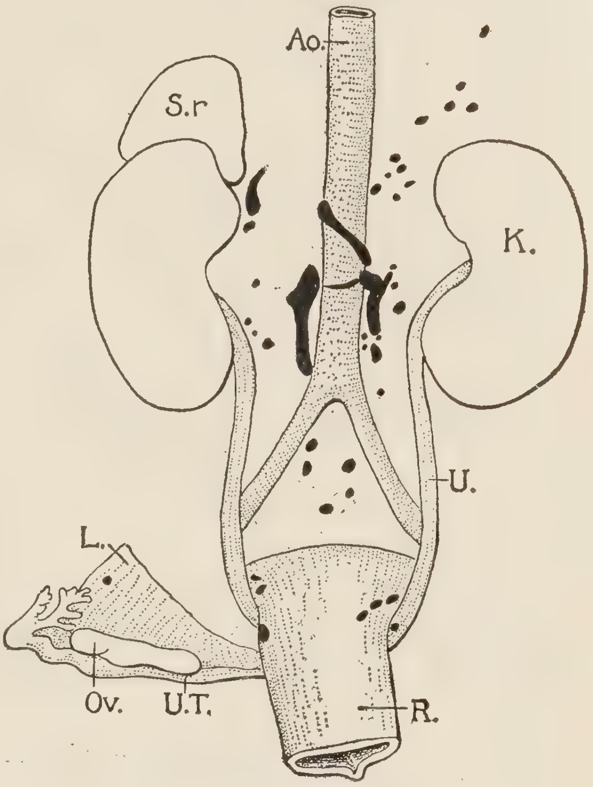

Fig. 157.—Diagram illustrating the minor chromaffin bodies of the posterior abdominal wall of a child 40 days old. Ao., aorta; K., kidney; L., broad ligament; Ov., ovary; R., rectum; S.r., right suprarenal; U., ureter; U.T., uterine tube. The chromaffin masses are indicated in solid black. (After Kohn.[237])

The structure of these masses is practically the same as that of the cortex of the suprarenal glands in the child. Lewis and Pappenheimer[239] state that involution processes take place in the accessory cortical masses as in the glands proper. In rare instances chromaffin (medullary) cells are found associated with the accessory cortical masses.

The Paraganglia (Fig. 147)

The various chromaffin bodies which are classified under this heading are well developed in early childhood. They are generally found associated with sympathetic plexuses of the larger arterial trunks, particularly those of the abdomen. The more important of these masses are listed below.

The aortic bodies, or organs of Zuckerkandl, are a pair of chromaffin masses located on either side of the abdominal aorta at the level of the origin of the inferior mesenteric artery. They are generally about 10 mm. long and 2 to 4 mm. broad. In about one-fifth of all cases the superior poles of the two masses are connected by an isthmus, but irregular forms are common. The bodies are composed of masses of chromaffin cells supported by a delicate connective tissue reticulum and surrounded by a definite fibrous capsule. They are intimately associated with the branches of the hypogastric nerve-plexus. The organs of Zuckerkandl are prominent at birth and increase somewhat in size in early childhood. In later childhood or adolescence they undergo partial degeneration and they are no longer macroscopically distinguishable in the adult, although chromaffin cells can be found in the positions which they formerly occupied.

Other minor chromaffin masses are found generally scattered in the retroperitoneal tissue of the posterior abdominal wall, associated with the female urogenital organs and the epididymis and prostate, and along the abdominal portion of the sympathetic cord.

In the thorax, chromaffin bodies occur regularly in the posterior parts of the intercostal spaces near the ganglia of the sympathetic cord. They are also found scattered along the coronary arteries, and around the base of the aorta and pulmonary artery (Busacchi[227]).

The carotid gland, which represents these bodies in the neck, has been observed in the bodies of newborn children and infants but no particular description has been given of it.

THE GLOMUS COCCYGEUM (LUSCHKA'S GLAND)

The glomus coccygeum is sometimes, probably erroneously, classified with the chromaffin bodies. Its structure in the infant has been investigated by Walker,[255] who finds that it is relatively as large at birth as in the adult and that it has in general the same form and structure as in maturity.

THE HYPOPHYSIS (Fig. 158)

The absolute weight of the hypophysis in the newborn is approximately 0.10 gm., about one-sixth the weight of the adult gland. The birth weight increases about one-half in the first year and is doubled in the third year. At seven years the body has attained about one-half its adult weight, and by the close of puberty its post-natal growth is five-sixths completed. The relative weight is much greater in childhood than in maturity. According to the statistics of Lucien,[240] it is about 0.003 per cent. at birth and in the first year, about 0.002 per cent. at puberty, and about 0.0015 per cent. in the adult. Throughout post-natal life the average relative weight is always distinctly greater in females than in males.

In infancy the hypophysis is about 10 mm. long, 7.5 mm. broad and 5 mm. thick; these dimensions are about two-thirds those of the adult body.

The anterior lobe of the infant is said to differ but little in structure from that of the adult. Both the clear, or chief, cells and the chromophile cells are present at birth, but the latter are small and few in number. The chromophile cells increase during childhood and are said by Erdheim[231] to be equal in number to the chief cells at the close of the first decennium. A distinct increase in the number of chromophile cells also occurs at puberty. The cyanophile cells appear earlier than the eosinophile. Fine fat-droplets are found in the epithelial cells at birth and increase in number throughout childhood.

The posterior lobe is richer in cellular elements and poorer in supporting fibers in infancy than in maturity. Colloid has been observed in the hypophysis both in infancy and in later childhood.

Accessory Masses of Hypophyseal Tissue (Fig. 158)

A constant mass of hypophyseal tissue, known as the pharyngeal hypophysis, is found in the connective tissue between the epithelium covering the vault of the pharynx and the floor of the skull just anterior to the pharyngeal tonsil. It is more prominent in childhood than in later life. According to Citelli,[228] the pharyngeal hypophysis is from 2 to 5.5 mm. long in later childhood. Its finer structure is similar to that of the anterior lobe of the hypophysis proper.

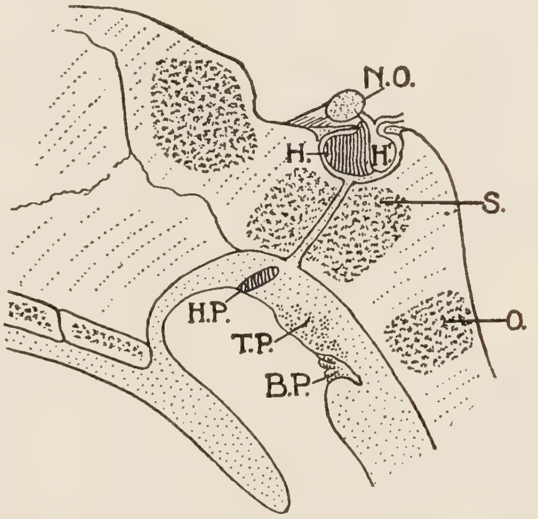

Fig. 158.—Semidiagrammatic drawing of the upper portion of the pharynx and the sphenoid bone in a newborn child illustrating the position of the pharyngeal hypophysis. B.P., bursa pharyngea; H., anterior lobe of hypophysis; H′, posterior lobe of hypophysis; H.P., pharyngeal hypophysis; N.O., optic nerve; O., ossification center of bone; S., ossification center of body of sphenoid bone; T.P., pharyngeal tonsil. The basipharyngeal canal which is shown passing through the basiphenoid bone is present in only five per cent. of children at birth. (After Testut, Traité d'Anatomie.)

In rare instances small nodules having the same structure as the anterior lobe of the hypophysis are found in the basipharyngeal canal, which sometimes pierces the body of the sphenoid bone, and also in the dura which lines the floor of the hypophyseal fossa. Figure 135 shows an example of the former anomaly.

The Pineal Body (Epiphysis Cerebri)

The pineal body or gland weighs about 0.01 gm. in the newborn. This weight is increased to about 0.05 gm. at the end of the first year and to about 0.10 to 0.12 gm. at ten years. Thereafter the growth of the organ is slight, the average adult weight being about 0.13 gm. In the young child both the neuroglia and the interneuroglia (or supposedly secretory) cells can be clearly distinguished. The organ begins to undergo involution at about seven years with the formation of neuroglial placques. The process of involution is said to have reached completion at 14 years.

THE ABDOMINO-PELVIC CAVITY AND THE PERITONEUM

In the newborn the abdominal portion of the body cavity is an ovoid space which is largest superiorly. Its transverse and anteroposterior diameters are greatest at a level a little above the umbilicus. Both of these diameters are relatively greater, both in comparison to the length of the abdominal cavity and to the total body-length, than in the older child and the adult. The posterior extensions of the cavity on either side of the vertebral column are less pronounced than in later life; and the reduction in the anteroposterior diameter of the lower part of the cavity, caused by the lumbar curve, is practically absent.

The pelvic portion of the body cavity is very small both absolutely and relatively at birth. It is more elongated than in later life and its cross section more closely approaches a circle. The pelvic cavity forms a less acute angle with the abdominal cavity in infancy than later because of the absence of the lumbar and sacral curvatures.

Although newborn and infant material has often been examined in connection with studies of the peritoneal reflections comparatively little work has been done toward determining the exact differences in these structures in infancy and maturity. Such data as we have indicate that the post-natal modifications are not great. Although one often encounters the statement that the peritoneal relations in the young infant approach the embryonic type more closely than they do in the adult, the few statistics which we have do not, in general, support this view. As Reid[269] has said: "Apart from inflammation, adhesions found in the fetus and young child are scarcely if at all less extensive than those found in the adult. Practically all are developed whilst the parts are actively growing, and the most obvious causes for their formation are the pressure exerted by the relatively enormous fetal colon; the anchoring of or traction exerted by the genito-mesenteric fold of the peritoneum; and the firm resistance against pressure of the large liver. . ." All of these factors are most active some time before birth and their influence in post-natal life is probably negligible. A general description of the peritoneum is therefore unnecessary, but a few minor peculiarities seen in early life may be mentioned.

At birth the greater omentum is relatively small. Its lower margin rarely extends below the level of the umbilicus. Its structure is extremely delicate, and elastic fibers are practically absent. Fat appears in the omentum, in the immediate vicinity of the larger vessels, about the eighth fetal month but it is still scanty in the newborn and infant. The openings, or fenestra, which are sometimes found in the adult omentum are said to appear after childhood. The fusion of the omentum with the mesentery of the transverse colon begins in fetal life, but is usually incomplete at birth. The fusion of the two layers of the omentum takes place at such different periods in different individuals that no general rule can be laid down regarding it.

The general line of attachment of the mesentery of the small intestine is much the same in the infant and adult, except that it becomes more vertical with the elongation of the lumbar region in childhood. The length of the mesentery (from its attachment to the posterior abdominal wall to the intestine) is said to be relatively greater in early life than in maturity.

The peritoneal relations of the duodenum are as variable in infants as in adults but, as a rule, the attachment of the tube to the posterior abdominal wall and surrounding structures is less complete than in later life. A detailed comparison of the attachments and fossæ in this region in the newborn and the adult will be found in one of the series of papers on the peritoneum by Ancel and Cavaillon.[261]

The peritoneal relations of the ileocecal segment of the intestine in childhood are dependent to a large extent upon its position. Alglave[259] found the terminal part of the ileum and the cecum were adherent to the right kidney and the duodenum when the former structures were in the lumbar position. When in the iliac position, the cecum was found to have the 'usual' relations, with a complete covering of peritoneum and retrocolic and laterocolic ligaments, in about one-fourth of all cases. In about one-fourth of the cases it was more adherent than the 'usual' type and in about one-half less adherent. When the ileocecal segment was in the pelvic position it was always mobile. The genito-mesenteric fold (ileopelvic band), the various forms of the parietocolic fold, and more or less extensive varieties of the "bloodless folds of Treves," with their concomitant fossæ, have been observed in the late fetus and newborn by Jonnesco,[101] Reid,[268, 269] Eastman,[263, 264] and others, but our data are not sufficiently extensive to warrant a statement as to the relative frequency of these structures in early life and maturity.

The presence of an ascending mesocolon in the adult is generally regarded as the persistence of an embryonic condition but the majority of observers who have examined large series of specimens find that a mesentery in this region is less common in children than in later life. Ancel and Cavaillon,[262] in particular, found no ascending mesocolon in seventy late fetuses and newborn children which they examined, while it was present in about one-sixth of their adult cases. Furthermore, they noted that the mesocolon in the latter cases was always composed of four layers of peritoneum—indicating that it was a secondary structure derived from the posterior abdominal wall after the primary two-layered mesocolon had fused with the parietal peritoneum of this region.

The transverse mesocolon is usually of considerable length in the newborn. Its fusion with the posterior layer of the greater omentum begins about the middle of fetal life, but is often incomplete at birth.

The descending mesocolon, like the ascending, is less frequent in childhood than in after life. Ancel and Cavaillon found it present in about one-sixth of their fetal and newborn material and in over one-third of adults. Like the ascending mesocolon, it is generally a secondary formation and is composed of four layers of peritoneum, but the primary type consisting of two layers is sometimes found.

The sigmoid colon of the infant almost always possesses a long mesentery. The line of attachment of this mesentery has the form of an inverted V, the apex of which is attached to the posterior abdominal wall near the median line, generally about the level of the umbilicus. A large fossa, the recessus intersigmoideus, lies between the two limbs of the line of attachment of the mesentery. This fossa is usually obliterated, from above downward, during childhood by the fusion of the left surface of the mesentery with the posterior abdominal wall.

The chief peculiarity in the pelvic peritoneum in infancy is the great relative depth of the recto-vesical pouch in the male and the utero-vesical pouch in the female. The former extends so far inferiorly that a part of the posterior surface of the prostate receives a peritoneal investment.

The peritoneal relations of the bladder in infancy vary greatly with the distension of that viscus. When the organ is contracted the peritoneum is reflected over it from the anterior abdominal wall about midway between umbilicus and pubis, but when it is fully expanded this point may lie as high as the umbilicus. The plica vesicalis transversa is usually well marked in young children.

The vaginal process of the male and the canal of Nuck (the corresponding structure in the female) are considered in connection with the descent of the testes and with the ovary (p. 361, p. 367). The peritoneal relations of the umbilical region are discussed in the section on the umbilicus (p. 403).

THE VASCULAR SYSTEM

The Fetal Circulation and the Fetal Blood Passages (Fig. 159)

The course of the blood in the late fetus is shown in diagrammatic fashion in Fig. 159. The "pure" or aterial blood from the placental capillaries enters the body through the single umbilical vein. It is carried through the intra-abdominal continuation of this vessel to the liver, where the umbilical vein is joined by the left branch of the portal vein carrying venous blood. The blood from the sinus formed by the union of these veins passes through the ductus venosus (D.V.) which joins with the inferior vena cava either directly or through the left hepatic veins. As the inferior vena cava is returning blood from the capillaries of the lower part of the body, there is a further mixture of venous and arterial blood at the point where it is joined by the ductus venosus. The inferior vena cava enters the posterior portion of the right atrium (auricle). The coronary sinus opening into the right atrium adds a little more venous blood to the main blood stream. The superior vena cava also opens into the right atrium (R.A.), and it carries venous blood from capillaries of the head and superior extremities. The ostium of the inferior vena cava is placed in the posterior part of the right atrium and immediately below and to the right of the foramen ovale, and its valve is so placed that it directs the blood stream towards this foramen. In spite of this anatomical arrangement, however, the blood of the inferior and superior vena cava is completely mixed in the right atrium. Of this fact we have positive evidence based upon experiments of Pohlman[289, 290] on living fetuses of animals.* The mixed blood of the right atrium passes in part into the right ventricle and thence into the pulmonary artery (P.A.). A part of the blood from the main pulmonary artery passes through its right and left branches to the lungs but the greater portion passes through the ductus arteriosus (D.A.) into the descending aorta. The part of the blood of the right atrium which does not flow into the right ventricle passes through the foramen ovale (F.O.) into the left atrium. Here it is joined by a small amount of venous blood which is returned by the pulmonary veins (P.v.) from the capillary bed of the lungs. The blood passes from the left atrium into the left ventricle and thence into the arch of the aorta (Ao.). After supplying the large arteries of the arch the remaining blood passes into the descending aorta where it is joined by the blood from the right ventricle, which comes through the ductus arteriosus (D.A.). The blood passing through the descending aorta supplies the various branches of this vessel and what remains flows into the umbilical arteries and thence to the capillaries of the placenta.

In following this scheme of the fetal circulation it will be noticed: First, but one vessel in the body of the fetus, the umbilical vein, contains strictly arterial blood and this vessel gives off no important branches of supply except to the liver. Second, the blood upon entering the right atrium from the inferior vena cava has already received venous admixtures from three sources—the portal vein, the inferior vena cava, and the hepatic veins. Third, there is a complete mixture of the blood of the superior and inferior venæ cavæ in the right atrium and a further addition of venous blood from the pulmonary veins in the left atrium. Consequently the blood which passes to the upper part of the body from the left atrium has been diluted with venous blood from five main sources since its entrance into the body through the umbilical vein, while the blood which passes from the right atrium through the pulmonary vein has been diluted by venous blood from four main sources.

The amount of blood in the fetal circulation just before birth

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* Pohlmann's experiments were performed upon living pig embryos in which the circulation was rapid and normal. Granules of starch which were injected into the umbilical vein were recovered from both the right and the left ventricles indicating that the blood from the umbilical vein passed through both the right atrio-ventricular orifice and the foramen ovale. Injections into the superior vena cava gave the same results, showing that blood from this source also passed through both the above-mentioned openings. These interesting and conclusive experiments are described in detail in the *Anatomical Record*, vol. iii, No. 2 (Feb., 1909).

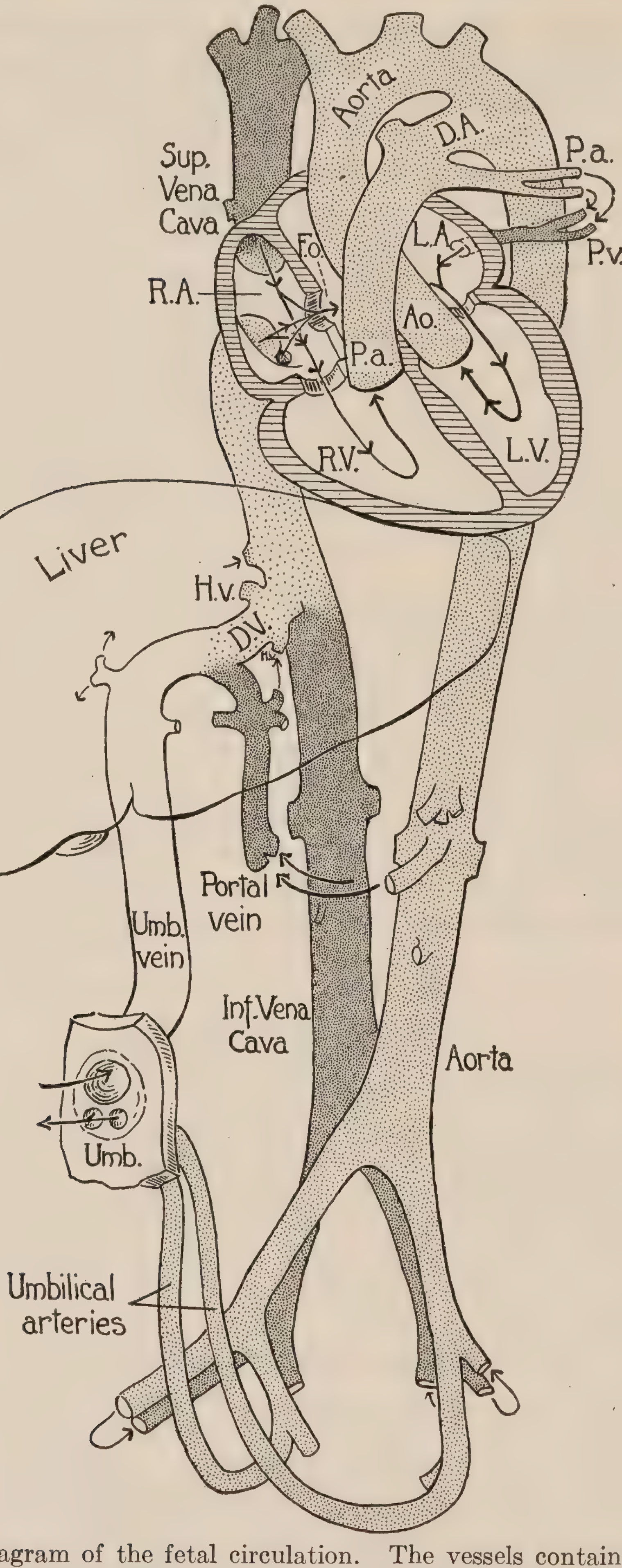

FIG. 159.—Diagram of the fetal circulation. The vessels containing arterial blood are represented in outline only, those containing venous blood in heavy stipple, and those containing mixed blood in light stipple. The course of the blood stream is indicated by arrows. Ao., aorta; D.A., ductus arteriosus; D.V., ductus venosus; F.o., foramen ovale; H.v., hepatic veins; L.A., left atrium (auricle); L.V., left ventricle; P.a., pulmonary artery; P.v., pulmonary vein; R.A., right atrium (auricle); R.V., right ventricle; Umb., umbilicus.

has been estimated to be between 250 and 350 c.c. It forms from one-thirteenth to one-ninth of the total body-weight at birth. About 100 c.c. of this blood is contained in the placental vessels and capillaries.

The change from the fetal to the post-natal type of circulation is brought about at birth by the closure of the fetal blood passages—the umbilical vessels, the ductus venosus, the ductus arteriosus, and the foramen ovale. In the closure of all of these passages we can recognize two processes—the physiological *occlusion* which, with the possible exception of the foramen ovale, takes place immediately after birth, and the anatomical *obliteration* of the lumina which may take place days, months, or even years, after birth. These changes are considered in the following pages along with the detailed descriptions of the fetal blood passages.

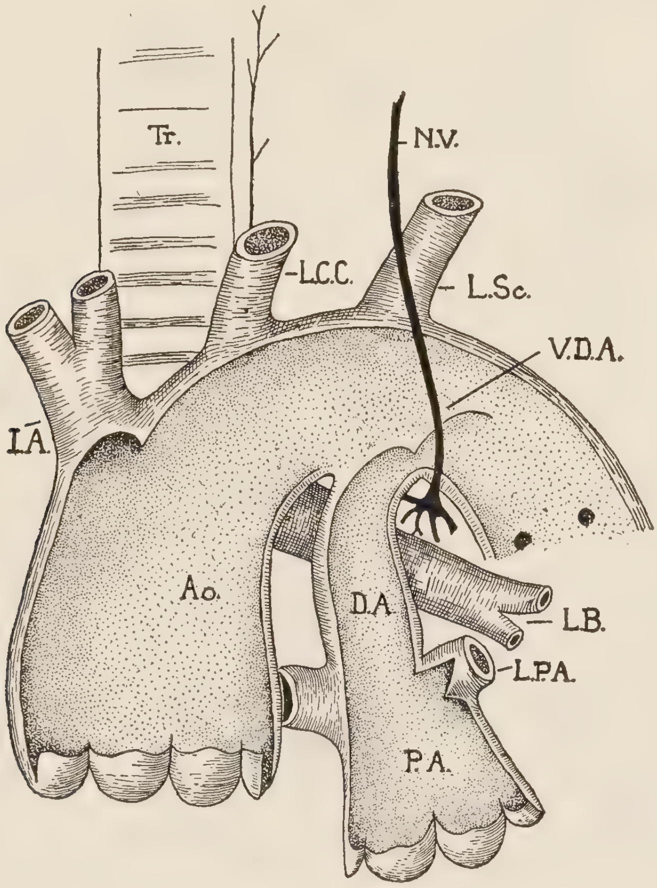

Fig. 160.—Diagram of the arch of the aorta, pulmonary artery and ductus arteriosus in the full-term fetus. Ao., aorta; D.A., ductus arteriosus; I.A., innominate artery; L.B., left bronchus; L.C.C., left common carotid artery; L.P.A., left pulmonary artery; L.Sc., left subclavian artery; N.V., vagus nerve; Tr., trachea; V.D.A., valve of the ductus arteriosus. (After Strassmann.[301])

The Ductus Arteriosus (Figs. 159, 160, 161, 162)

The ductus arteriosus is a short trunk connecting the pulmonary artery with the upper part of the descending aorta. It arises as a direct continuation of the pulmonary artery at the point where that vessel gives off its right and left branches to the lungs, and joins the aorta at its medial border just below the point of origin of the left subclavian artery. The ductus arteriosus joins the aorta at an acute angle (30 to 35°), and the aortic orifice of the ductus is therefore somewhat elongated. Along the upper and right margin of this orifice there is found a more or less prominent flap termed by Strassmann[301] the valve of the ductus arteriosus (Fig. 160). It is, however, a fold between the ductus and the aorta rather than a true valve.

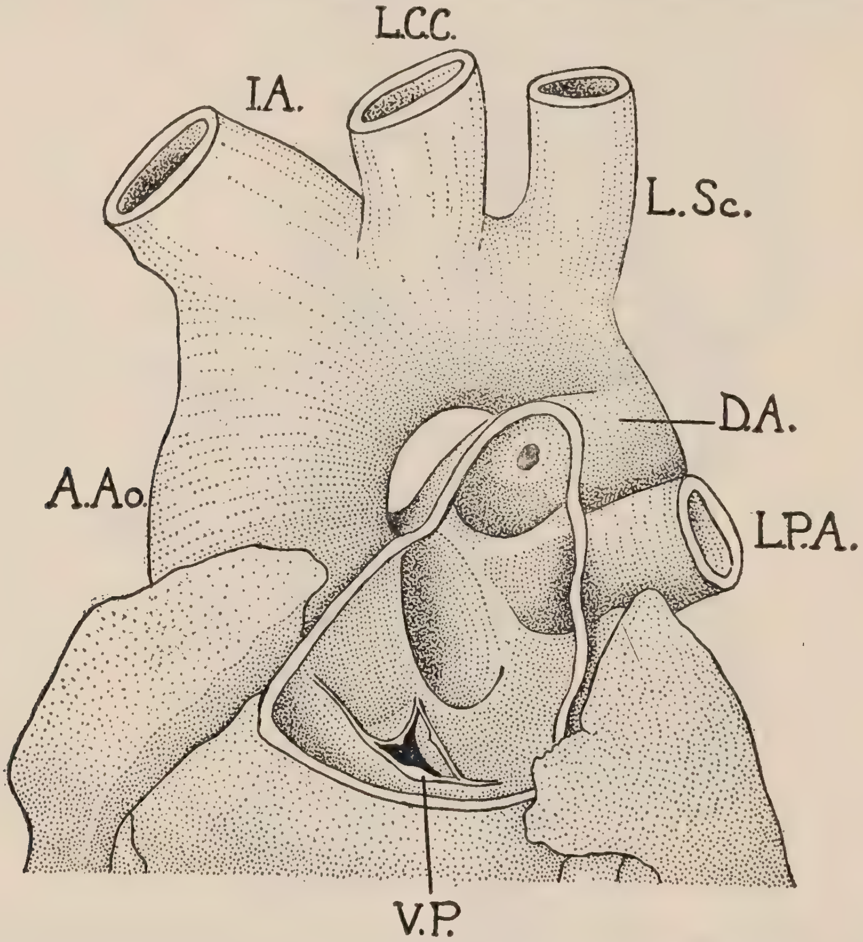

Fig. 161.—Dissection of the pulmonary artery in the newborn child. A.Ao., arch of the aorta; D.A., ductus arteriosus; I.A., innominate artery; L.C.C., left common carotid artery; L.P.A., left pulmonary artery; L.Sc., left subclavian artery; V.P., valves of pulmonary artery. (After Sclavounos.[298])

The length of the ductus arteriosus at birth is extremely variable, but in the majority of cases it is between 8 and 12 mm. The caliber is about 3 mm. During the first three months of post-natal life, according to the observations of Gérard,[282] the ductus lies posterior to the left half of the sternum at the level of the lower part of the first intercostal space or the second rib. It descends during infancy to the level of the second intercostal space. The vessel is entirely extrapericardial in almost all cases. It is in contact with the left bronchus below, and the thymus gland covers it anteriorly. Its relations to the pulmonary arteries and the aorta are shown in Figs. 160, 161.

The finer structure of the ductus does not differ greatly from that of other large arterial trunks. The tunica intima is of considerable thickness. The lamina elastica interna is well marked and the tunica media is of the usual structure although perhaps containing less elastic tissue than does the media of the aorta. There is no definite lamina elastica externa although there are numerous separate elastic fibers in this region. The adventitia blends with the loose connective tissue surrounding the vessel.

Two distinct processes can be recognized in the closure of the ductus arteriosus as in the other fetal blood passages: The lumen of the vessel is occluded immediately after the establishment of respiration but it is not obliterated until a much later time. A great number of theories have been advanced to explain the occlusion of the ductus at birth but, in the opinion of the writer, none are entirely free from legitimate objection. To discuss or even present these theories in any detail would require much more space than is available here but they may be classified into the five general groups as follows:

(*a*) **Theories postulating the compression of the ductus** by structures such as the bronchi when distended with air at the first inspiration; by the left bronchus with the extension of the head during or immediately after birth; or by connective tissue bands extending from the ductus to the diaphragm, which are pulled downward with the descent of the latter. (Most of the hypotheses of this class are of ancient origin and are not considered seriously at the present time.)

(*b*) **Theories Postulating the Reduction of the Lumen of the Ductus through the Change in Position of the Heart at Birth.**—This movement has been interpreted both as stretching the ductus and thus reducing the caliber of its lumen, and as causing a kinking of the vessel with a mechanical obliteration of its cavity.

(*c*) **Theories Postulating a Reduction in the Pressure of the Pulmonary Artery to a Point Equal to or below That of the Aorta with a Consequent Collapse of the Wall of the Ductus.**—Under this heading may be placed the hypothesis of Strassmann,[301] that the increased pressure in the aorta presses the fold of the ductus arteriosus against the orifice of that vessel. Strassmann supports his view by injection experiments. These have been repeated by several other workers, sometimes with negative and sometimes with positive results. Here also may be placed the theory that the collapse of the wall of the vessel occurs at the time when the falling pressure in the pulmonary artery and the rising pressure in the aorta are exactly equal, and a temporary stasis occurs in the ductus.

(*d*) **Theories Postulating the Formation of a Thrombus in the Ductus.**—(These may be thrown out of court, as less than 1 per cent. of the ducts contain a thrombus at autopsy.)

(*e*) **Theories Postulating an Activity in the Wall of the Vessel.**—These may be placed in two groups—those assuming a muscular contraction of the vessel and those assuming an occlusion through the rapid proliferation of connective tissue of the intima.

The reader desiring detailed information on this subject is referred to the papers of Gérard,[282] Strassmann,[301] Schultze,[297] Haberda,[285] Wells[305] and Kirstein.[288]

The obliteration of the ductus is better understood. Even before birth there is a proliferation of the subendothelial tissue of the intima of the vessel. After birth, with the closure of the vessel, the process is accelerated. There is a hyperplasia of the connective tissue and elastic fibers of the intima, and of the inner part of the media as well; the lining endothelium disappears; and the lumen is filled with new connective tissue. This process generally begins in the middle part of the vessel and extends toward its extremities. A small depression in the wall of the descending aorta marks the position of the former ostium of the ductus for some time after obliteration is completed. The published data on the time of the obliteration of the ductus arteriosus have been collated by Norris and Scammon. Less than 1 per cent. of all cases show an obliteration of the lumen in the first ten days after birth. A period of rapid obliteration begins at about two weeks and continues until the end of the third month, at which time about one-half of all cases are obliterated. After this time the percentage of obliterations increases very slowly until the end of the first year when about 95 per cent. of all cases show complete obliteration. After one year the ductus is closed in practically all normal children.

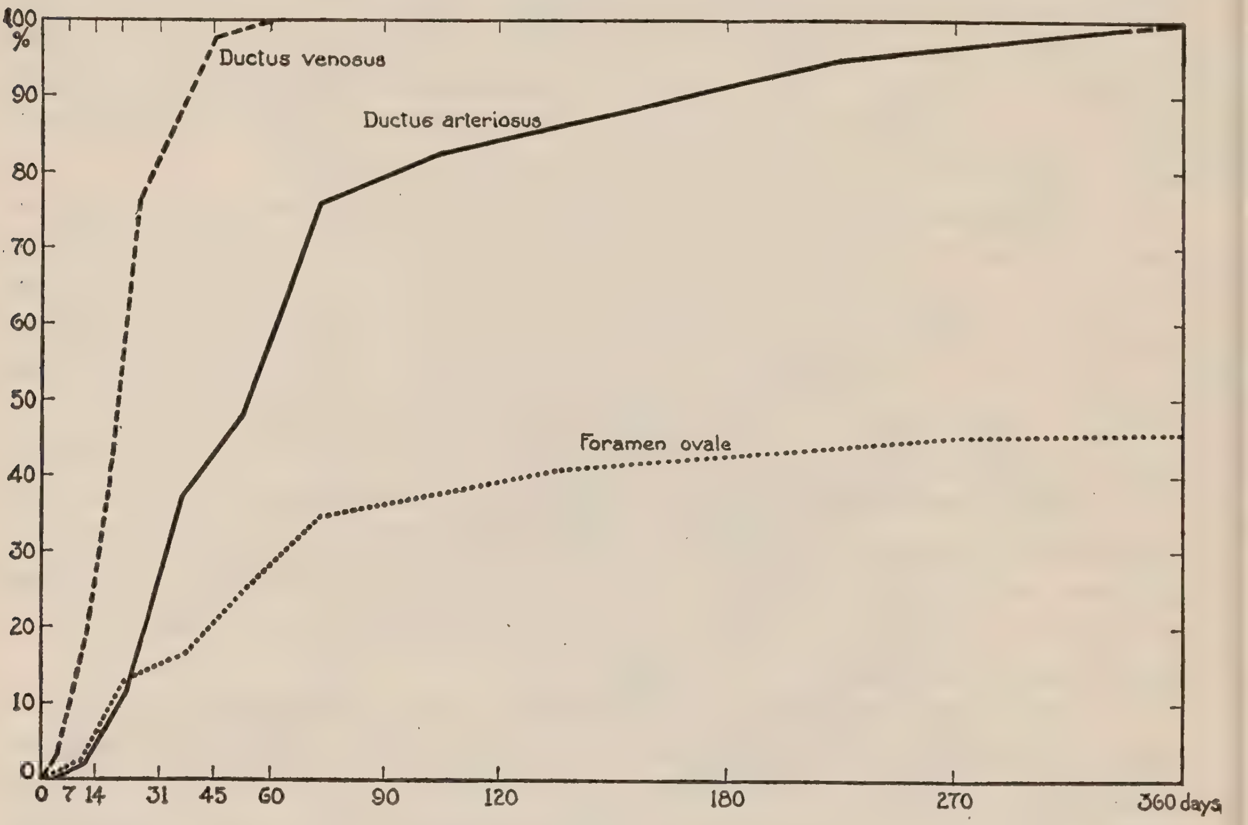

FIG. 162.—A graph illustrating the obliteration (in per cent.) of the fetal blood-passages in the first year. (After Scammon and Norris.[296])

THE DUCTUS VENOSUS (Figs. 159, 162, 163)

The ductus venosus, or duct of Arantius, is a venous trunk which arises from the left branch of the portal vein just opposite the mouth of the umbilical vein, and terminates in the vena cava or more commonly in the left hepatic vein just before that channel joins the inferior vena cava. It lies in the fossa for the ductus venosus between the left and caudate (Spigelian) lobes of the liver. In the newborn it is located practically in the median sagittal line of the body at the level of the ninth and tenth thoracic vertebræ. At the time of birth the ductus venosus is 2 to 3 cm. in length and from 2 to 4 mm. in diameter. In about two-thirds of the cases a small and probably non-functioning valve is found at the portal end of the vessel.

The ductus venosus has the structure of a muscular vein. The thick intima of the vessel is surrounded by a media consisting mainly of circularly arranged muscular fibers mixed with a considerable amount of elastic and some fibrous tissue. The adventitia of the vessel fuses with the surrounding connective tissue of the fossa and contains elastic fibers which have no regular arrangement.

Obliteration of the ductus venosus generally begins in the second week of post-natal life and the lumen is impervious to a probe in most cases by the end of the second month. Obliteration begins at the portal end of the vessel and extends to the caval orifice. Often a funnel-like pocket from the left hepatic vein or vena cava inferior marks the position of the superior opening of the ductus venosus for a long time after birth. A small vein is generally found in the center of the ligament of the ductus venosus in later life. This vessel is not the remains of the ductus venosus, but is a new one which penetrates the connective tissue which fills the lumen of the original vessel. It is connected with the supra-umbilical veins below, and with the peripheral venules which are found in the surrounding connective tissue of the fossa of the ductus venosus.

THE FORAMEN OVALE (Figs. 159, 164, 166, 167)

The foramen ovale is an aperture which connects the posterior part of the right atrium (auricle) with the left atrium throughout fetal life and for a variable period after birth. It is bounded by a rounded ridge, the limbus fossæ ovalis or annulus of Vieussens, and is guarded on the left by a more or less extensive valve. The long axis of the foramen lies in the median line of the body, while the plane of the opening corresponds almost exactly to the frontal plane. Consequently the flow of blood through the foramen is from before backward and the old custom of placing the child on the side to aid in the closure of the valve at birth is without an anatomical basis. At birth the foramen is from 4 to 6 mm. in length and 3 or 4 mm. in breadth.

The valve of the foramen ovale is a membranous flap which is attached to the superior and posterior margins of the left side of the opening. It consists of a fold of endothelium enclosing a core composed of small strands of cardiac muscle separated by delicate connective tissue fibers, and a small amount of elastic tissue.

The foramen ovale is probably functionally closed after the first respiration. With the return of more blood to the left atrium from the pulmonary veins the pressure rises in this chamber and forces the valve against the margins of the foramen. The obliteration of the opening is a much slower process and never takes place in at least a fourth of all cases. Norris and Scammon[296] have collected the published data on the closure of the foramen in childhood. They find that the foramen is obliterated in less than 3 per cent. of all cases in the first two weeks of life. After this period obliteration proceeds more rapidly until the fourth month when approximately

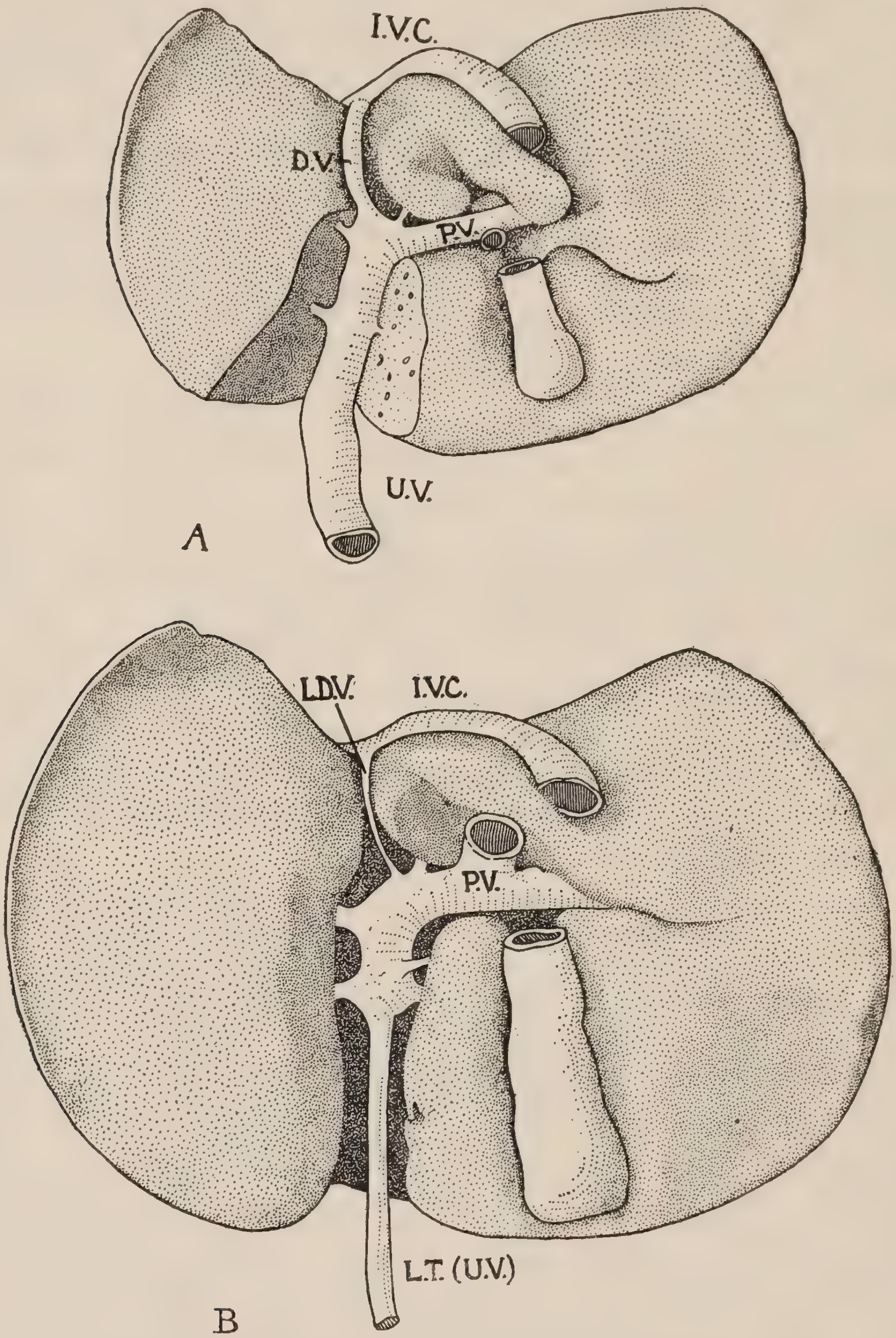

Fig. 163.—Views of the inferior surfaces of the livers of two children (A, newborn; B., one month old) showing the post-natal changes in the umbilical vein and ductus venosus. D.V., ductus venosus; I.V.C., inferior vena cava; L.D.V., ligament of the ductus venosus; P.V., portal vein; L.T., ligamentum teres; U.V., umbilical vein. (After Richter.[295])

one-third of all cases are obliterated. After three months the percentage of obliterations rises very slowly until maturity when about 72 per cent. of all cases show a complete closure of the aperture.

According to Hintze,[286] the obliteration of the foramen is brought about by the irritation caused by the free margin of the valve rubbing against the margin of the aperture. By this irritation the cells of the surface endothelium are destroyed and a proliferation of the underlying connective tissue is induced which results in the fusion of the valve with the margin of the opening.

THE UMBILICAL ARTERIES (Figs. 121, 132, 147, 151, 159, 170)

The umbilical arteries form the direct continuation of the hypogastric (internal iliac) arteries in the full-term fetus. Arising near the upper margin of the lesser pelvis, they run forward beside the ureters and gain the posterior surface of the anterior abdominal wall. They then pass upward on either side of the bladder and urachus, and turning over the lower margin of the umbilical ring enter the umbilical cord. The umbilical arteries give off small branches to the bladder and ureters.

The umbilical arteries, at their origins, have practically the same structure as the other larger arterial trunks, but as they approach the umbilicus their lumina become small and irregular and their walls are greatly thickened. The thickening of the walls of the arteries in the neighborhood of the umbilicus is due mainly to the increase in the number of longitudinal smooth muscle fibers in the inner part of the tunica media. While elastic tissue is abundant in this segment of the vessels the lamina elastica interna is broken up into a number of discrete fibers. As the arteries pass into the mucus connective tissue of the umbilical cord their external coats receive investments of fibrous tissue termed mantel zones. At this level, also, the thickness of the muscular coats is again reduced and the lumina of the vessels are indented by a series of irregular elevations and spirally arranged folds known as the valves of Hoboken.

The post-natal changes which convert the upper segments of the umbilical arteries into the lateral umbilical ligaments cover a considerable period. Immediately the umbilical cord is severed the arteries undergo a contraction so that the flow of blood from their cut ends is generally entirely arrested even though they are not ligated. Thrombi are often formed in the distal ends of the arteries. The actual obliteration of the lumina is brought about by the proliferation of connective tissue in the tunica media and tunica intima of the vessels. Evidences of this proliferation are seen in the walls of the vessels some time before birth. Obliteration proceeds centripetally, and by the close of the second or third month the vessels are usually closed down to the level of the superior vesical artery.

The umbilical arteries usually undergo some longitudinal retraction. This process is apparently an extremely irregular and variable one. Haberda[285] found that it was usually first evident in the third week when the vessels were generally less than 1 cm. below the umbilicus. In children of three months the retraction amounted on the average to 4 or 4.5 cm., and the ends of the arteries lay at the level of the apex of the bladder. The nature of this retraction is still incompletely understood.

The Umbilical Vein (Figs. 123, 127, 132, 151, 159, 162, 163, 170, 171)

The intra-abdominal portion of the umbilical vein is about 2 cm. in length in the newborn. Arising as the direct extension of the umbilical vein of the funis, it extends upward and a little to the right from the umbilical ring to the porta hepatis where it joins the right branch of the portal vein, forming a sinus of some size. Throughout the greater part of its course it is inclosed between the layers of the falciform ligament. Before joining the portal vein the umbilical trunk gives off several large intrahepatic branches which are distributed directly to the liver tissue.

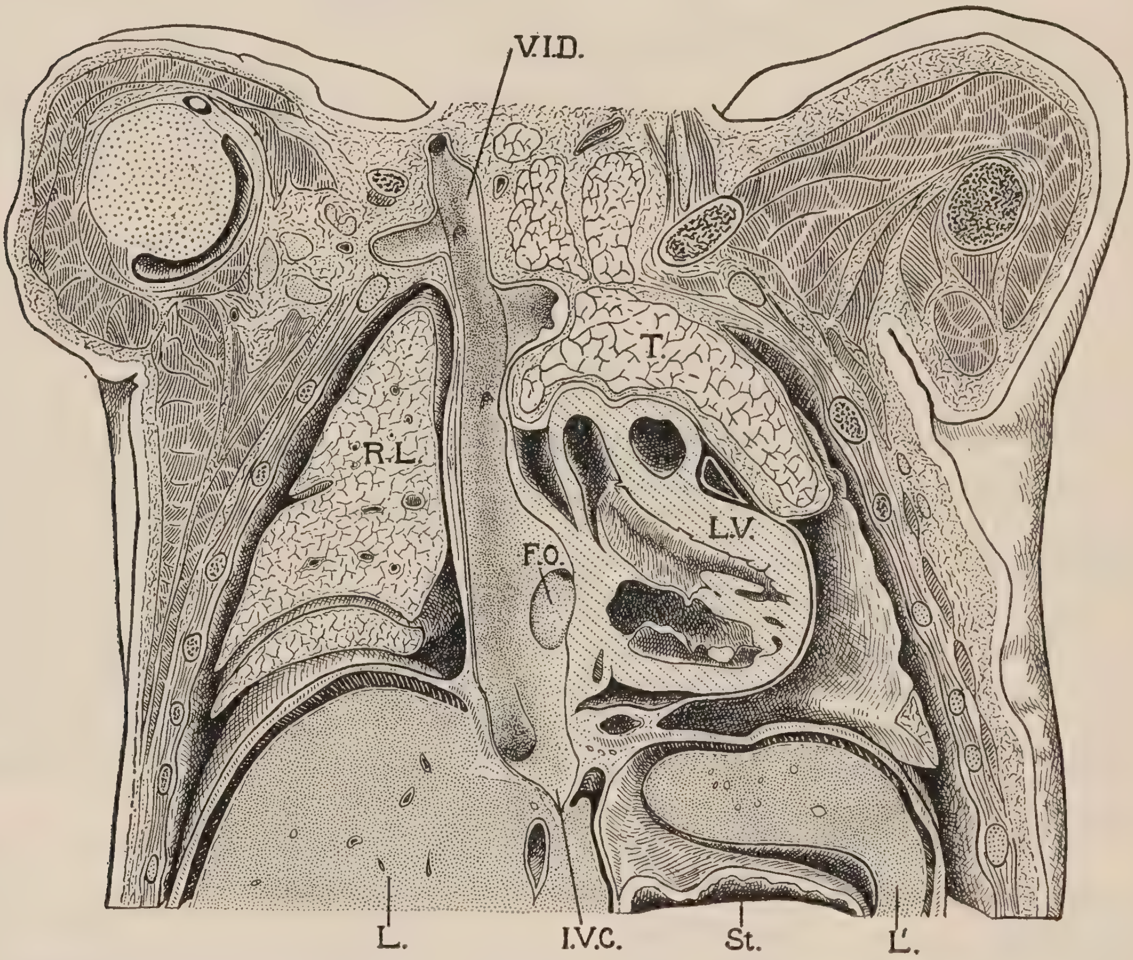

Fig. 164.—Frontal section of the thorax of a premature child of the 7th fetal month. F.o., foramen ovale; L., L′, liver; I.V.C., inferior vena cava; L.V., left ventricle; R.L., right lung; St., stomach; T., thymus; V.I.D., right innominate vein.

As compared with the umbilical arteries the vein is thin walled and has a large lumen. The tunica interna is not sharply marked off from the media by an elastic membrane in the intra-abdominal portion of the vein although a definite elastica interna is present at the umbilical ring. The media is composed of bundles of smooth muscle many of which are directed longitudinally and obliquely. These bundles are embedded in a large amount of connective tissue which also contains some elastic fibers. The intra-abdominal part of the vein has an adventitia which also contains elastic tissue.

The post-natal involution of the umbilical vein is somewhat similar to that of the umbilical arteries. The vessel contracts when it is severed, although not as vigorously as do the arteries, and a thrombus is sometimes formed in its lumen. In the immediate vicinity of the umbilicus there is an infiltration of the lumen by connective tissue in the first week, but above this point the cavity remains patent for some time although it is much reduced in size. It is usually about two months before the lumen is obliterated to the level of the lower margin of the liver and small closed cysts may persist long after this time. The vein undergoes some retraction after birth.

Closely associated with the umbilical vein is the set of vessels known as the parumbilical veins. These vessels arise as extensions of the inferior epigastric veins and of the vesical plexus, and after passing upward along the umbilicus enter the falciform ligament. Here they may either run along the ligamentum teres to anastomose with the portal vein, or a vessel may penetrate the ligament and pass upward through its core to join the portal. The vessel which is found in the ligament was at one time regarded as the remains of the umbilical vein but it is now considered a new growth similar to the vein found in the ligament of the ductus venosus. The parumbilical anastomosis is permeable to injection fluids in about two-thirds of all children under four years and in about two-fifths of adults (Haberda[285]). In cases of portal obstruction its elements may develop into vessels of considerable size.

THE HEART (Figs. 122, 123, 160, 164, 165, 166, 167, 168, 169)

The absolute weight of the heart in the full-term newborn child is 20 to 25 gm. This weight is doubled in the first two years of life, tripled in four years, and increased about sixfold by puberty. There is a rapid increase in the heart weight during adolescence, and the heart of the adult weighs from 10 to 13 times that of the newborn. The relative weight of the heart of the newborn is distinctly greater than that of the adult. At birth the heart forms 0.65 to 0.80 per cent. of the total body-weight. With the great increase in body-weight during the first year, this percentage drops rapidly to about 0.45. During the second year the relative heart weight again rises to about 0.50 and this relation obtains, with individual variations, throughout the remainder of childhood and maturity. If the weight of the heart of the newborn be compared to the combined weight of the body and the fetal placenta, it is found that the relation which the organ bears to the tissues which it supplies with blood is little if any greater than in the adult.

According to the statistics of Müller,[291] the weight relations of the atria (auricles) and ventricles change somewhat during childhood. At birth and during the first year the weight of the ventricles is to that of the atria as four or five to one. From the first year on the ventricles grow more rapidly than the atria so that the weight relation between the two is little less than six to one in later childhood and a little more than six to one in adult life.

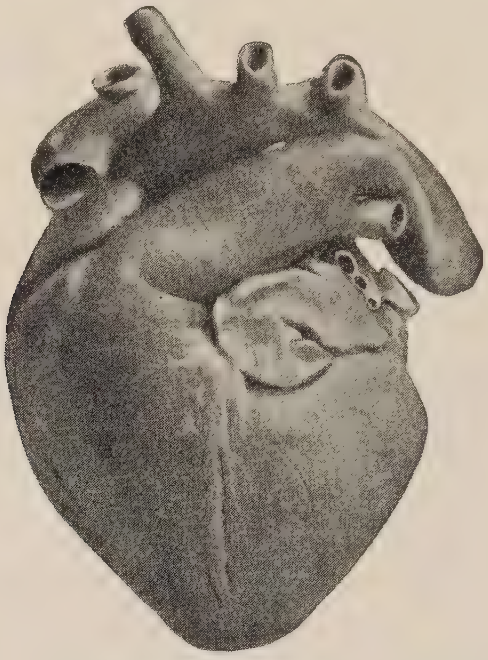

FIG. 165.—Left anterior view of the heart of a full-term newborn child. Natural size.

In the newborn, according to the observations of the same author, the left ventricle weighs about one-fourth more than the right one. But the left grows so rapidly that by the end of the second year it weighs twice as much as the right and from that time on to puberty even a little more. From puberty until the end of the fourth decade the left ventricle is approximately twice the weight of the right one.

The difference in the post-natal development of the right and left ventricles is also illustrated by the changes in thickness of their lateral walls. At birth the average thickness of the lateral walls of the right and left ventricles is approximately equal (about 5 mm.) but by the end of the first month the left one is distinctly the thicker. At the end of the second year the wall of the left ventricle is twice as thick, and by puberty three times as thick as the right.

The dimensions of the heart are very variable in early life and the possibilities of error in their measurement are great. Consequently, in the opinion of the writer at least, no great value can be assigned to the descriptions of Barthez and Rillet[277] and others of minor changes in the dimensional relations of the organ in childhood. In general it may be said that the dimensional increase in the heart in early childhood is not as great as its weight increase or, in other words, the weight increase of the organ is caused by the growth in thickness of its walls rather than by their general expansion. In later childhood the rates of weight and of dimensional increase are more nearly equal. Table 23 below is a summary of the observations of Bizot on this subject.

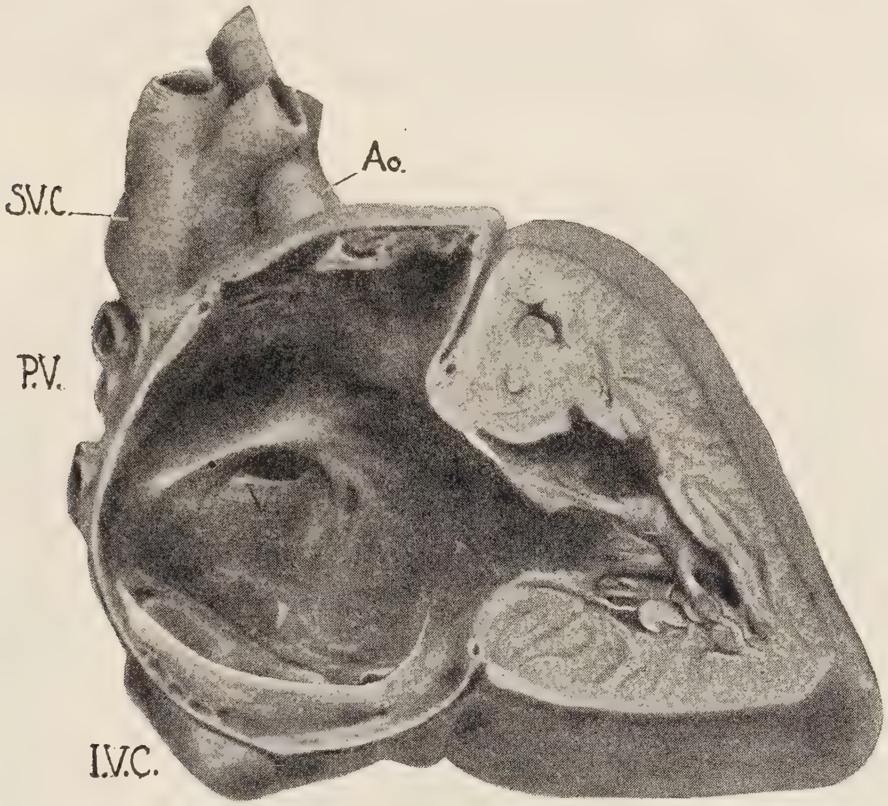

FIG. 166.—Dissection of the heart of a full-term stillborn child, showing the cavities of the left atrium (auricle) and ventricle. Ao., aorta; I.V.C., inferior vena cava; P.V., pulmonary veins; S.V.C., superior vena cava; V., valve of foramen ovale. Twice natural size.

TABLE 23.—THE DIMENSIONS OF THE HEART IN CHILDHOOD (AFTER BIZOT[279])

Age	Length, centimeters	Breadth, centimeters	Thickness, centimeters
Boys			
1 to 4 yrs.	5.14	6.09	2.44
5 to 9 yrs.	7.04	7.44	2.89
10 to 15 yrs.	7.67	8.35	3.16
Girls			
1 to 4 yrs.	5.10	5.83	2.28
5 to 9 yrs.	6.0	6.54	2.55
10 to 15 yrs.	6.59	7.04	2.84

Bardeen[276] has recently investigated the post-natal changes in the weight and volume of the heart by means of teleroentgenography of the living. His findings by this method are somewhat different from the older anatomic ones. According to his calculations, which have been carefully checked by experimental work on cadavers, the weight of the heart in the newborn is about 30 gm. This is increased five-fold in the first six years, ten-fold by puberty and fifteen-fold by the close of the second decade. The volume of the heart, in diastole, is about 35 to 40 c.c. at birth. This is increased about seven-or eightfold in the first decade and from sixteen- to eighteen-fold by the close of the second decade.

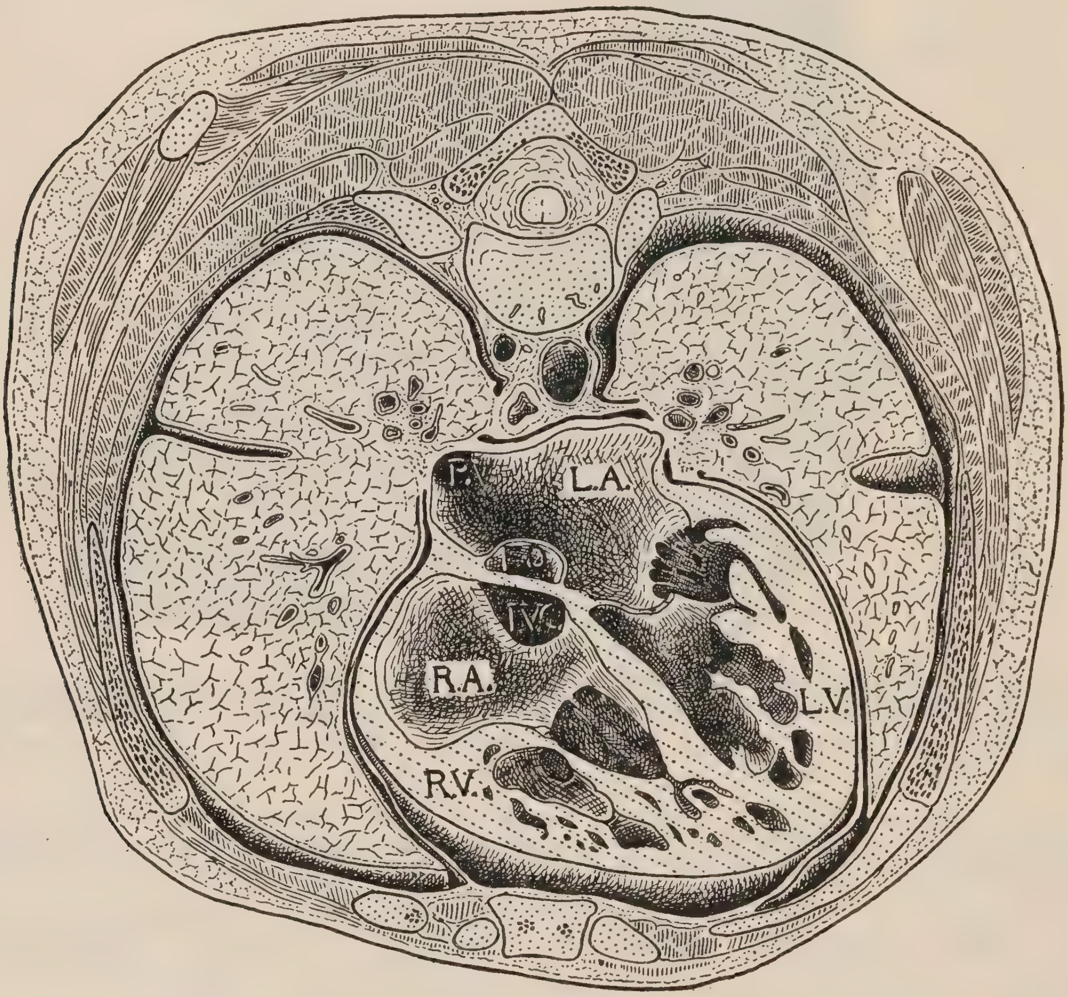

Fig. 167.—Transverse section of the thorax of a newborn child passing through the four chambers of the heart. F.O., foramen ovale; L.A., left atrium (auricle); L.V., left ventricle; I.V.C., inferior vena cava; P.V., pulmonary vein; R.A., right atrium (auricle); R.V., right ventricle. Natural size.

In the full-term infant in which respiration is well established the heart lies practically mid-way between the crown of the head and the pelvic extremity of the trunk.* It lies in front of the vertebral column from the fifth to the eighth or ninth thoracic vertebræ and behind the lower half or more of the sternum and the costal cartilages of the third, fourth, fifth, sixth and sometimes seventh rib on the left side. The axis of the heart is more nearly transverse than in later life. The apex is generally placed in the fifth intercostal space on or just lateral to the left mammillary line. The apex beat is usually found in the fourth intercostal space (von Stark,[300] Troitzky[304]).

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* All anatomic data on the position of the heart in the newborn and young infant are to be accepted with caution. After death, with the body in dorsal decubitus, the large liver tends to fall downward and forward and the delicate diaphragm and associated ligaments are unable to support it. With the displacement of the liver the heart also is pulled downward and the normal relationships are considerably altered.

In the young infant, as in the adult, the greater part of the anterior surface of the heart is formed by the right atrium and right ventricle. The bare area of the heart is relatively larger at birth than in later life, and the greater part of the anterior wall of the right ventricle and sometimes a little of the left ventricle and the right auricular appendage come in contact with the anterior chest wall. As the lungs acquire their full expansion in the first week after birth the extent of the bare area is somewhat reduced. The thymus generally covers the anterior surface of the right atrium except for the auricular appendage and may also extend a little over the base of the right ventricle.

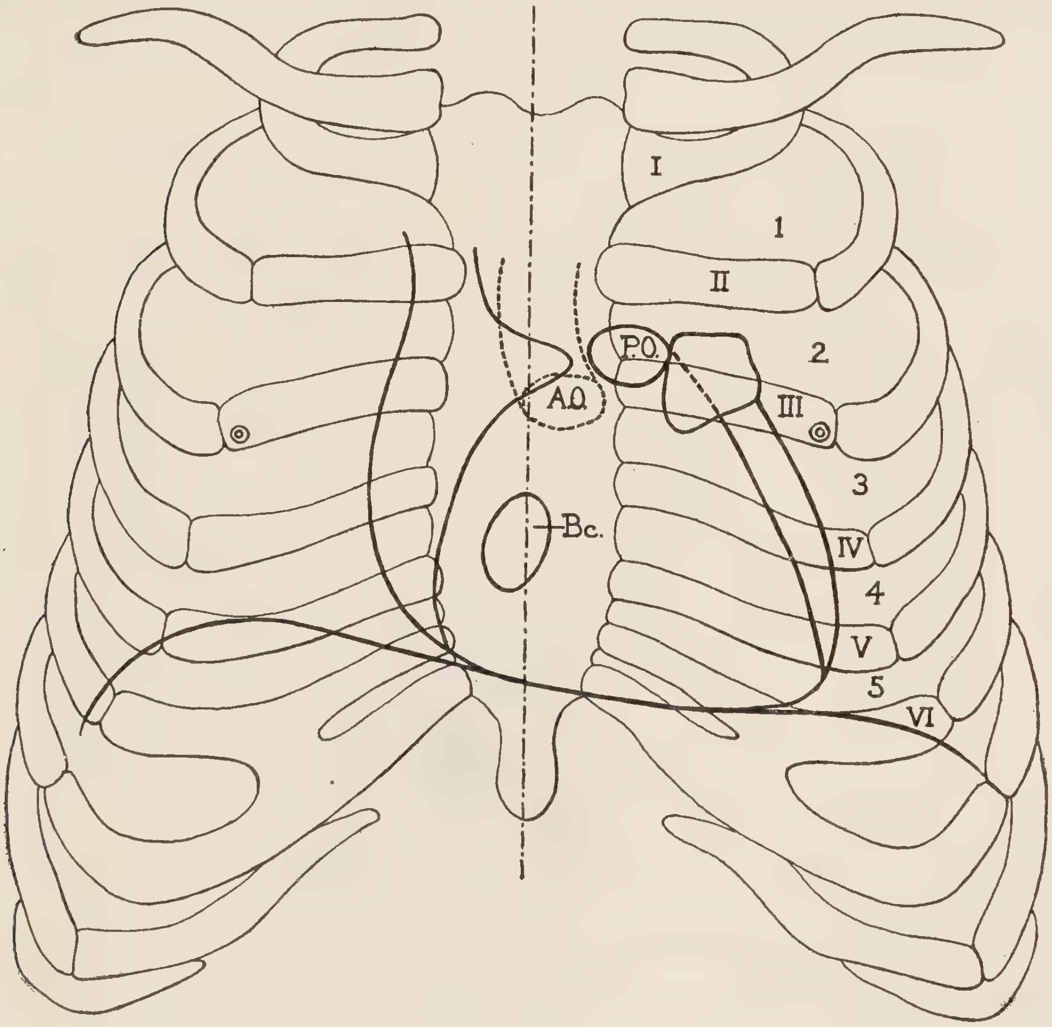

Fig. 168.—Outline of the anterior wall of the thorax of a newborn child showing the position of the heart and some of the cardiac orifices. A.O., aortic orifice; Bc., bicuspid valve; P.O., pulmonary orifice. The ribs are indicated in Roman numerals and the intercostal spaces in Arabic numerals. (After Mettenheimer.[12])

The position of the orifices and valves of the heart in relation to the skeleton in the newborn is shown in Figs. 167, 168. The pulmonary orifice lies at the juncture of the upper part of the third rib with the left margin of the sternum. The aortic orifice lies under the cover of the left half of the sternum at the level of the third rib. Th mitrals or bicuspid valve is a little to the left of the mid-line of the sternum at the level of the third intercostal space and the fourth ribs. Its surfaces lie practically in the frontal plane of the body. The tricuspid valve lies to the right of the mitral and at a slightly lower level (fourth rib, fourth intercostal space and sometimes fifth rib). The foramen ovale lies with its long axis in the median line of the body at the level of the third intercostal space. The valve of the foramen ovale is almost exactly in the frontal plane of the body.

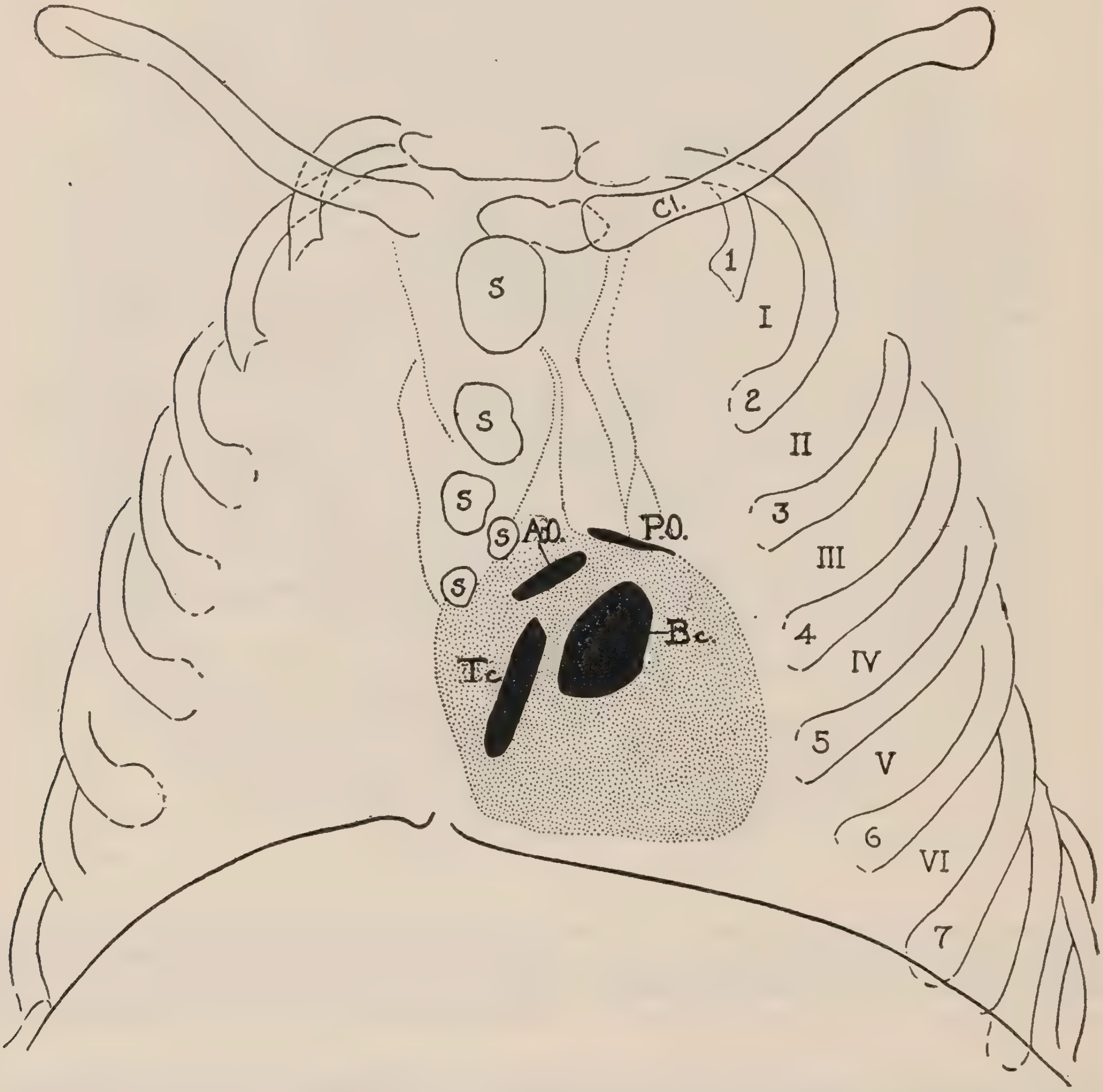

FIG. 169.—An outline drawing of a radiograph of the thorax of a newborn child; Lead plates were inserted in the cardiac orifices and appear as black areas in the figure. The ribs are numbered in Arabic, the intercostal spaces in Roman numerals, A.O., aortic orifice; Bc., bicuspid valve; Cl., clavicle. P.O., pulmonary orifice; S., ossification centers of the sternum; Tc., tricuspid valve. (Modified from Debierre, Looten, Beun, Tramblin, et Lheureux.[230])

We have very few anatomical data regarding the change in position of the heart during childhood, but the results of the methods of physical diagnosis show that the organ is gradually shifted downward and a little to the right. According to the observations of von Stark[300] the apex beat is most commonly found in the fourth intercostal space during the first year of life. From the second to the seventh years it may be in the fourth or the fifth intercostal space or in both. After the seventh year it is almost always in the fifth intercostal space. Until the end of the third year the point of the apex beat is generally lateral to the left mammillary line; in the fourth, fifth, and sixth years it is commonly upon it; and thereafter it is medial to the mammillary line in the majority of cases. The change in the relation of the apex beat to the mammillary line is due both to the movement of the beat medially and to the shifting of the mammæ laterally along with the growth of the anterior chest wall. The conclusions of von Stark are supported by the observations of other and later authors.

The Post-natal Growth of the Blood-vessels

According to the observations of Thoma,[303] the average cross-section area of ascending portion of the arch of the aorta is about 28 square mm. in the newborn and during the first 10 days of post-natal life. This area is doubled in the second year, increased fivefold by five or six years, and increased about tenfold by the middle of the third decade. By this time the body-weight is increased about twenty-fold and the weight of the heart about fifteen-fold. Thus in proportion to the body-weight the lumen of the aorta is twice as great in the newborn as the adult and in proportion to the heart weight nearly one and one-half times as great. The change in these relations begins in infancy but proceeds very slowly during the first period of childhood. It is much more rapid just prior to and during puberty but is not completed until early maturity.

The relation of the caliber of the arch of the aorta to its branches is also greatly modified in childhood. At birth the combined cross-section area of the vessels which conduct blood away from the arch of the aorta (the descending part of the thoracic aorta, innominate artery, left common carotid, and left subclavian arteries and smaller arterial twigs) is not quite equal to that of the vessels which carry blood to the arch (the ascending aorta and ductus arteriosus). But with the closure of the ductus arteriosus the cross-section area of the stream supplying the aortic arch is suddenly reduced to almost half that of the vessels which carry the blood away from the arch. According to the measurements of Thoma, this discrepancy is adjusted, in a large measure, in the first years by the relatively small increase in the caliber of the branches which carry blood away from the arch. However, the cross-section area of the vessels of supply and drainage does not become equal until maturity.

The history of the abdominal aorta is also striking. The cross-section area of this vessel is 16.5 mm. in the newborn and about 80 mm. or five times as much, in the adult. In the meantime, the volume of the part of the body supplied by this vessel increases about thirty-fold. Thus the abdominal aorta is relatively nearly six times larger in section at birth than in early maturity. The closure of the umbilical arteries affects the abdominal aorta much as the amputation of a limb affects its arterial trunk of supply; and during early infancy the vessel actually undergoes a reduction in caliber of about one-fourth. This post-natal reduction is not recovered until the second year. While the caliber of the ascending aorta at birth is considerably less than that of vessels which it supplies the abdominal artery is considerably larger than the combined cross-section area of its branches. This inequality persists to some extent throughout early life and maturity although it is most marked in infancy.

The larger arterial trunks which supply the head and neck and the extremities enlarge to some extent in accordance with the post-natal growth of these parts, but the relation is not a very exact one. Thoma's measurements indicate that the cross-section area of both common carotid arteries is increased about fivefold between birth and the middle of the third decade and the volume of the head and neck also increases about fivefold. On the other hand the left subclavian artery only increases about sevenfold while the volume of the left upper extremity increases nearly sixteen-fold.

The post-natal growth of the arteries which supply the viscera has not been studied in great detail. The table of Nikiforoff[292] quoted below shows some of the differences in the relative blood supply of the larger organs in the newborn and adult.

We know almost nothing of the post-natal growth in length of the arteries. Some observations made many years ago by Schwalbe[299] indicate that the absolute length of the aorta increases about threefold between birth and maturity. The lower part of the abdominal aorta apparently grows a little more than the remainder of the vessel.

TABLE 24.—RELATIVE BLOOD SUPPLY OF ORGANS AT BIRTH AND IN THE ADULT (AFTER NIKIFOROFF[292])

Organ	Relative blood supply*	
	Newborn	Adult
Lungs	0.92	2.25
Kidneys	0.85	3.14
Heart	0.83	3.42
Spleen	0.66	3.00
Digestive tube	0.62	1.25
Liver	0.36	1.88
Brain	0.14	1.56

In fetal life the growth in thickness of the walls of arteries takes place almost entirely in the tunica media and externa, while the interna remains almost unchanged from the fourth fetal month until birth. After birth, however, the tunica interna grows much more rapidly than the tunica media. According to the observations of Aschoff[274, 275] and Gründstein,[284] the media of the common carotid artery is practically doubled between birth and maturity, and the media of the aorta is more than tripled. During the same period the tunica interna of the carotid increases sixfold and that of the aorta more than tenfold. Apparently most of the growth in the media takes place before puberty. Sometimes a considerable growth of the intima is noted as early as five years.

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*Relative blood supply equals total caliber of supplying vessels divided by 1/100 of the weight of the organ.

Although the absolute thickness of the walls of arteries increases considerably during childhood the relative thickness, as compared to the diameter of the lumen of the vessel, is steadily diminished.

The venous system in infancy is less developed, on the whole, than in later life. The statement is made that the volume of the arterial and the venous systems is about equal in infancy while the capacity of the veins is about double that of the arteries in maturity; but I have been unable to find any direct statistical evidence in support of it. The course of the smaller veins is straighter in children than in adults and the valves are relatively more numerous and more efficient. There is said to be a considerable growth of the veins about puberty.

THE UMBILICUS (Figs. 121, 132, 147, 151, 159, 170, 171, 172)

The umbilicus of the full-term newborn is located about 1.5 cm. below the mid-point between the crown of the head and the soles of the feet. With the growth of the inferior extremities it assumes a higher position. At one year it is practically the mid-point between the crown and the sole. In the adult approximately three-fifths of the body length is inferior to the umbilicus.

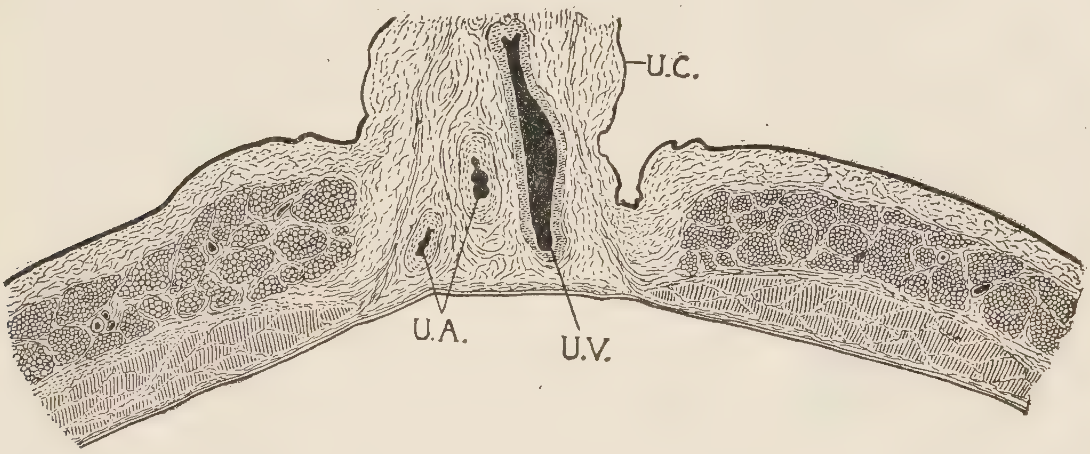

FIG. 170.—A cross section of the umbilicus of a full-term newborn child. U.A., umbilical artery; U.C., umbilical cord; U.V., umbilical vein. One and one-half times natural size.

The umbilicus of the newborn consists of the base or root of the umbilical cord with the vessels contained within it; the umbilical skeleton which is made up of a number of structures of fibrous connective tissue; and the peritoneum which forms its posterior covering. These three main portions will be considered separately.

The fibrous skeleton of the umbilicus is formed mainly from the linea alba. As this structure approaches the umbilical region it becomes considerably wider. In the center of this widened area is a gap or aperture through which the umbilical vessels pass from the cord to the abdominal cavity. This aperture is surrounded by a thickened margin known as the umbilical ring. The umbilical ring is formed by the interlacing of the oblique fibers from the two sides of the linea alba and, like that structure, is composed of white fibrous tissue. The presence of elastic fibers and smooth muscle in the

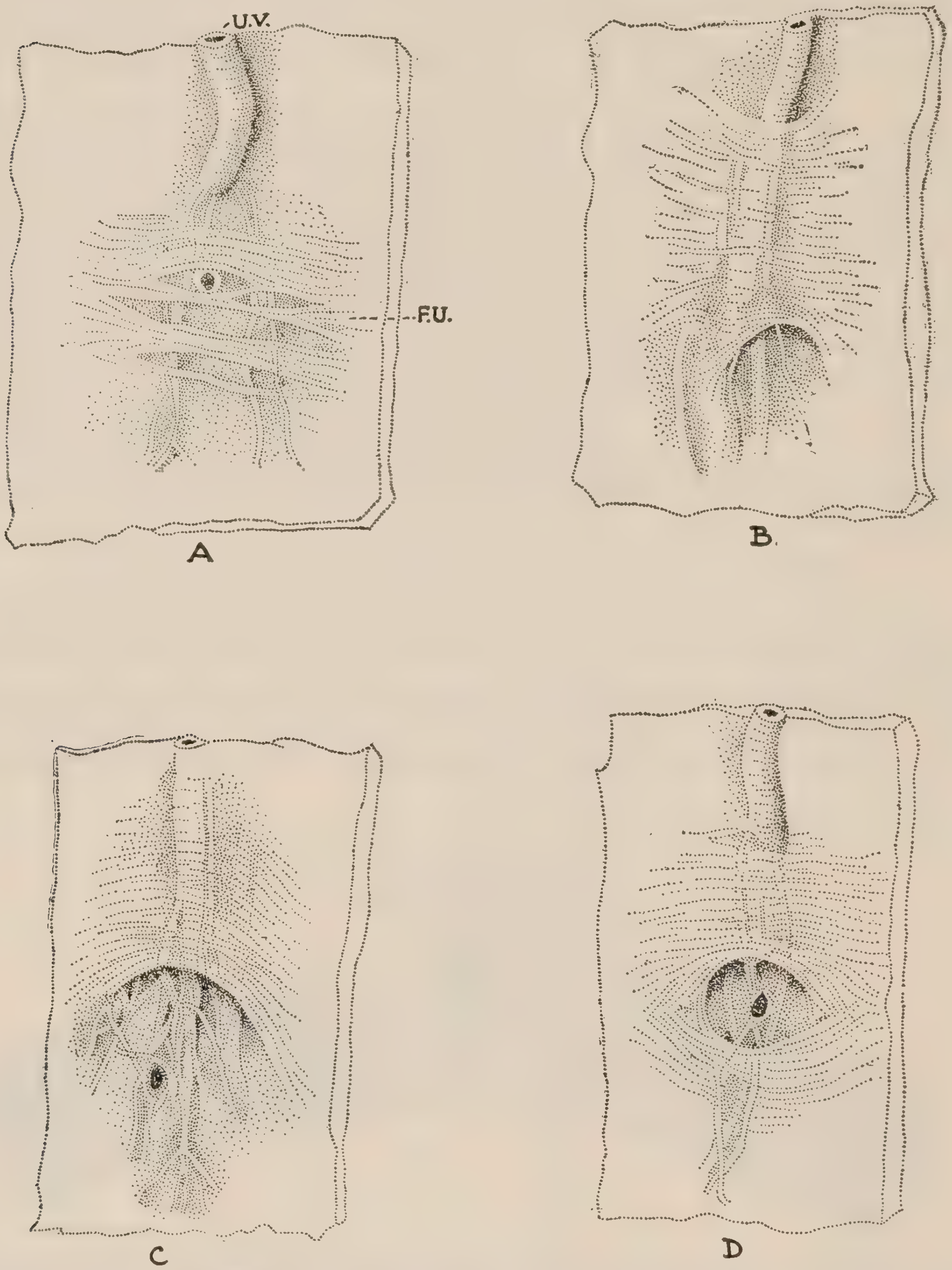

Fig. 171.—Drawings of the peritoneal surface of the umbilical region of four children three to four months old. F.U., umbilical fascia; U.V., umbilical vein. (After Sachs.[315])

umbilical ring, which was described by older writers, has not been confirmed by modern investigation. The umbilical arteries and the fibrous cord which represents the urachus are attached to the lower margin of the ring, while the umbilical vein forms a less firm connection with the upper margin. The umbilical ring is in contact with the superficial fat and fascia anteriorly and with the transversalis fascia posteriorly. The latter is generally thin and inconspicuous in this region but in some cases its fibers are considerably thickened, and form prominent transverse bands which pass across the umbilical region and which are known as the umbilical fascia. The arrangement of these fibers is shown in Fig. 171. As will be seen in this figure, the fascia is generally much better developed over the upper than over the lower half of the umbilical aperture.

The umbilical cord at its fetal end consists of an external covering of simple cuboidal or squamous epithelium which encloses a core of mucus connective tissue, or jelly of Wharton. Imbedded in this jelly are the two umbilical arteries and the single umbilical vein. The epidermis of the abdomen extends out a centimeter or so from the attachment of the cord before passing over into the simple epithelium which covers the remainder of that structure. The jelly of Wharton fuses with the connective tissue of the superficial fascia and projects to a variable degree into the umbilical opening. The two umbilical arteries run side by side to the lower margin of the umbilical ring and, passing over this structure, continue their intra-abdominal course along either side of the urachus. As has been pointed out in the description of the umbilical arteries, the outer parts of their adventitious coats are condensed into a fibrous layer sometimes known as the mantle zone. As the arteries pass over the inferior portion of the umbilical ring the free edges of the mantle zones fuse with this structure. The umbilical vein turns upward as it goes through the umbilical ring and passes over the superior margin of that structure. As it does so it forms a weak fibrous connection with the ring above and a considerably stronger one with the arteries below. The vein, after crossing the superior margin of the umbilical ring, runs a short way in a canal bounded by the posterior surfaces of the recti muscles in front and the transversalis fascia behind; it then passes into the falciform ligament.

The peritoneum posterior to the umbilicus is reflected over the umbilical arteries and vein and the umbilical ring. As a rule its surface is smooth but it may be reflected around the superior and inferior margins of the umbilical fascia or project as a pocket into the space which sometimes intervenes between the vein and the upper or lateral margins of the umbilical ring.

The blood supply of the umbilicus comes from the small arterial springs from the superior vesical arteries below, the inferior epigastric arteries laterally and from the hepatic arteries above. These vessels inosculate posterior to the umbilical ring forming a circle termed by Hyrtl[309] the circulus arteriosus umbilicatus. From this circle small vessels pass through into the connective tissue of the umbilicus and supply it and the covering integument. They form a subcutaneous plexus which extends out on the umbilical cord a little beyond the line of termination of the epithelium of the body-skin. The venous drainage of the umbilicus is mainly through the parumbilical veins.

The lymphatic drainage of the umbilicus has been carefully studied by Cunéo and Marcille[307] whose illustration is reproduced in Fig. 172. Following these authors the lymphatics can be divided into three sets: (1) the cutaneous lymphatics; (2) the lymphatics of the fibrous nucleus; (3) the lymphatics of the umbilical ring proper. The cutaneous lymphatics arise from the skin overlying the umbilical ring and run downward immediately under the integument, to terminate in the superficial inguinal glands. Those of the fibrous nucleus arise around that structure; they pass laterally and, piercing the sheath of the rectus abdominis, reach the deep epigastric artery; they follow the course of the artery to the posterior wall of the rectus sheath where they join with the other lymphatics which drain this region. The lymphatics of the umbilical ring are divided into an anterior and a posterior set. The anterior lymphatics arise around the umbilicus on the anterior surface of the sheath of the rectus. Part of them join with the lymphatics of the nucleus and part join

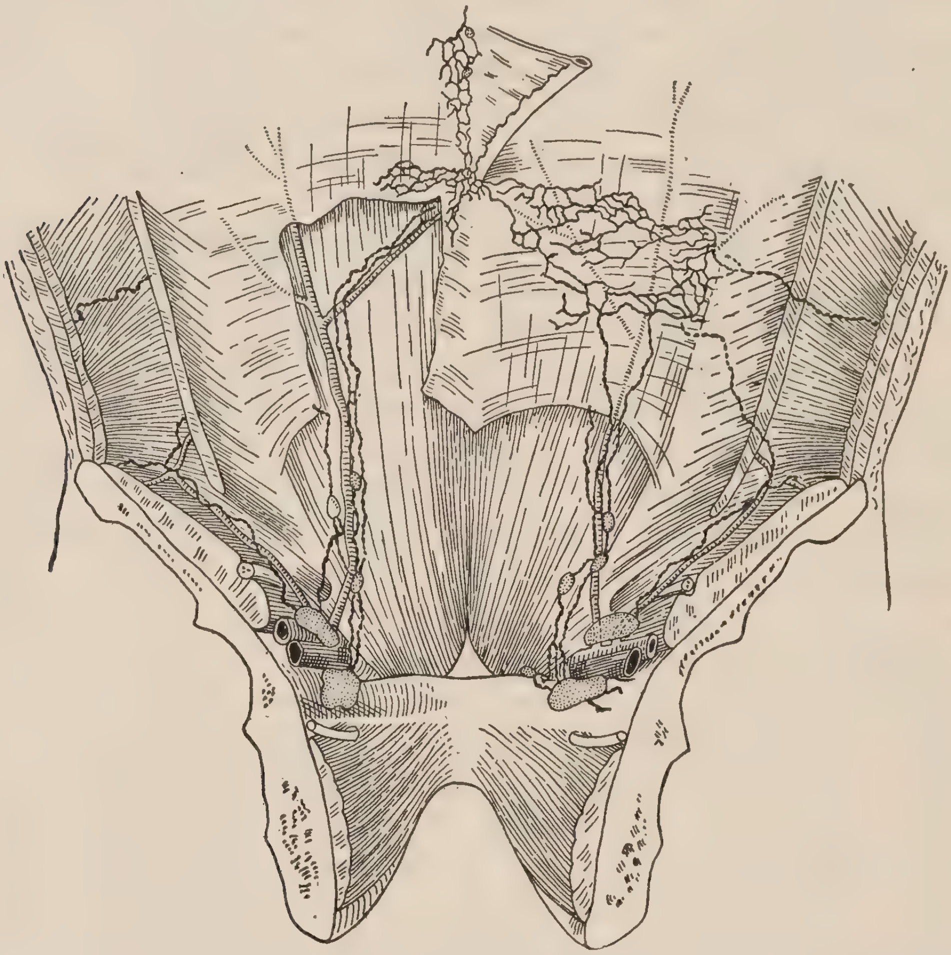

FIG. 172.—Posterior view of the anterior abdominal wall of a newborn child, showing the deep lymphatic drainage of the umbilical region. (After Cunéo et Marcille.[307])

the posterior ones. The posterior lymphatics lie on the posterior surface of the rectus. Part of the trunks draining them join with some of those from the anterior lymphatics and pass to the anterior retro-crural gland or a juxta-aortic gland. Others, joining with the lymphatics of the fibrous nucleus, pass along the deep epigastric artery to terminate in the external iliac glands. Small lymph glands are found in the subperitoneal tissue both above and below the umbilicus in the infant. Both the umbilical arteries and the umbilical vein are supplied with lymphatics which follow them as far as the umbilicus and a centimeter or so into the cord. The lymphatics of the vein join those of the portal fissure of the liver while those of the arteries communicate with those of the bladder.

After the ligation of the umbilical cord at birth the stump which remains undergoes desiccation and at the close of a few days is cast off as a foreign body. In the meantime, the skin covering the margin of the umbilical ring begins to fold in at the base of the stump, first at its inferior margin and later around its entire circumference. There is thus formed a crater-like depression to the floor of which is attached the mummified remains of the umbilical cord. When the stump of the cord is finally detached there is exposed a small area covered with granulation tissue and containing the obliterated ends of the umbilical vessels. The skin lining the sides of the umbilical funnel quickly grows over this area and completes the cutaneous umbilicus. At the same time the delicate connective tissue which formerly constituted the root of the umbilical cord is rapidly converted into a dense fibrous mass which remains throughout life as the nucleus of the umbilicus. These changes are usually completed by the end of the third week of life.

The causes of the umbilication of the ring are still obscure. The traction of the contracting and retracting umbilical vessels; the supposed sphincter-like action of the umbilical ring; and the pull of the umbilical arteries due to the change in the shape of the abdomen and the position of the body after birth have been suggested as factors in the process. Meyer[312] has recently contributed an excellent discussion of this problem.

The changes in the umbilical vessels after birth have already been considered.

THE LYMPHOID ORGANS (INCLUDING THE THYMUS)

The Lymphatic Glands

Our knowledge of the anatomy of the lymphatic glands in children, particularly of their finer structure and growth, is still extremely fragmentary. At birth the size of these structures varies from microscopic proportions to that of a large pea. They are of pinkish color, being almost entirely free from the surrounding fat which gives them the yellowish shade seen in later life. The connective tissue capsule and trabeculæ which form the supporting framework are very thin and delicate, and the reticular tissue network is composed of cells richer in protoplasm than those of the adult gland. The lymphoid tissue is very abundant and is arranged peripherally in large, rather indistinct nodules which are less numerous than in the adult. Germinal centers are hardly ever seen in the lymph-glands of the newborn. According to Gundobin,[7] they first appear in the second month of postnatal life and do not stand out plainly until the third year. Although present and of considerable diameter, the peripheral lymph-sinuses are often inconspicuous in the newborn and adult, because of the number of lymphocytes which they contain.

The amount of lymphoid tissue segregated in the lymph-nodes is considerable at birth, increases steadily during childhood, and after puberty undergoes at least a relative reduction. The increase during childhood is due in part to the growth of the glands already present at birth and in part to the formation of new glands. Wullenweber,[334] who has made the most careful study we possess on this subject, found that the average weight of the individual mesenterial lymph-gland increased nearly 20 times between birth and maturity while their number increased about three times. The number of palpable superficial glands at different ages has been studied in a large series of cases by Dietrich[318] and his results are given in tabular form below. Certain glands, such as the supra and infra-umbilical and the anterior tibial glands, generally disappear entirely after puberty.

TABLE 25.—THE PALPABLE SUPERFICIAL LYMPH-GLANDS AT DIFFERENT AGES (AFTER DIETRICH[318])

		Gland groups				
		Occipital	Cervical	Axillary	Cubital	Inguinal
Percentage of cases in which glands are palpable	Children to 12 years....	5.4	100.0	92.7	96.3	100.0
	Youths 13 to 20 years...	5.3	81.9	69.1	77.4	91.4
	Adults 21 and over.....	0.68	74.7	68.9	81.7	92.0
Average number of glands palpable in each group	Children to 12 years....	1–2	7–8	3–4	circa 6	8–9
	Youths 13 to 20 years...	1	3	2	2	6–7
	Adults 21 and over.....	1	2–3	1–2	1–2	7

THE SPLEEN (Figs. 127, 128, 129, 132, 147, 156, 173)

The weight and dimensions of the spleen are very variable at birth as they are indeed during all periods of life. Omitting all cases of proved or suspected lues congenita, the writer found an average spleen-weight of 13.5 gm. in a series of 150 full-term newborn children. The weight of the organ at birth may vary, however, from 5 to 20 gm. even in cases where lues is rigidly excluded. The spleen approximately doubles in weight during the first year of life, and is tripled during the third; thereafter the growth is slower. The total weight increase from birth to maturity is about twelve-fold, or something over half that of the total gain in body-weight. The dimensional growth of the spleen is shown in Table 26 which is a summary of an extensive series of cases collated by Stricker.[333] All cases of gastro-enteritis have been excluded from this series.

TABLE 26.—THE DIMENSIONS OF THE SPLEEN IN CHILDHOOD (Summarized From Stricker[333])

Age	Number of cases	Average length, centimeters	Average breadth, centimeters	Average thickness, centimeters
Newborn under 3000 gm. body-weight	141	4.0	2.5	1.0
Newborn 3000 gm. and over body-weight	174	5.0	3.0	1.0
1 to 6 months	141	5.6	3.2	1.5
6 to 12 months	32	6.7	3.9	1.6
1 to 2 years	44	6.8	3.7	1.7
2 to 3 years	30	7.2	4.1	1.7
3 to 6 years	74	8.0	4.6	2.0
6 to 9 years	40	8.4	5.0	2.5
9 to 12 years	38	9.7	5.9	2.2
12 to 15 years	26	11.8	6.5	2.6
15 to 21 years	97	12.1	8.2	3.0

The relations of the spleen in the newborn and young infant differ considerably from those observed in later life. In the newborn the long axis of the organ is generally vertical or oblique. The superior margin, according to the studies of Fleury,[320] lies most commonly at the level of the eighth rib although it may be as high as the seventh or as low as the ninth. The lower margin generally lies at the level of the eleventh rib although it may be as high as the tenth or as low as the umbilical line. Macè[327] found that the spleen was palpable under the costal margin in 6 per cent. of healthy newborn children of non-syphilitic mothers. The spleen of the young infant has two general surfaces: a lateral one which is in contact with the diaphragm and, in many cases, with the margin of the left lobe of the liver; and a medial one which may be subdivided into colic, gastric and suprarenal surfaces in contact with these organs. The form and positions of the contact areas of the medial surfaces of the spleen are shown in Fig. 173. The pancreas is in contact with the hilus of the spleen in the infant as in the adult. The organ is entirely prepleural in position (Jackson[10]). The change from the relations described to those of the adult are brought about rapidly during the early part of childhood through the *relative* decrease in the size of the liver and the left suprarenal. As the size of the latter organ remains practically stationary in the first two years of post-natal life, the kidney gradually replaces the suprarenal in its relation to the posterior part of the medial surface of the spleen. As the stomach increases in size it apparently displaces the spleen to the left but does not press it downward in the abdominal cavity.

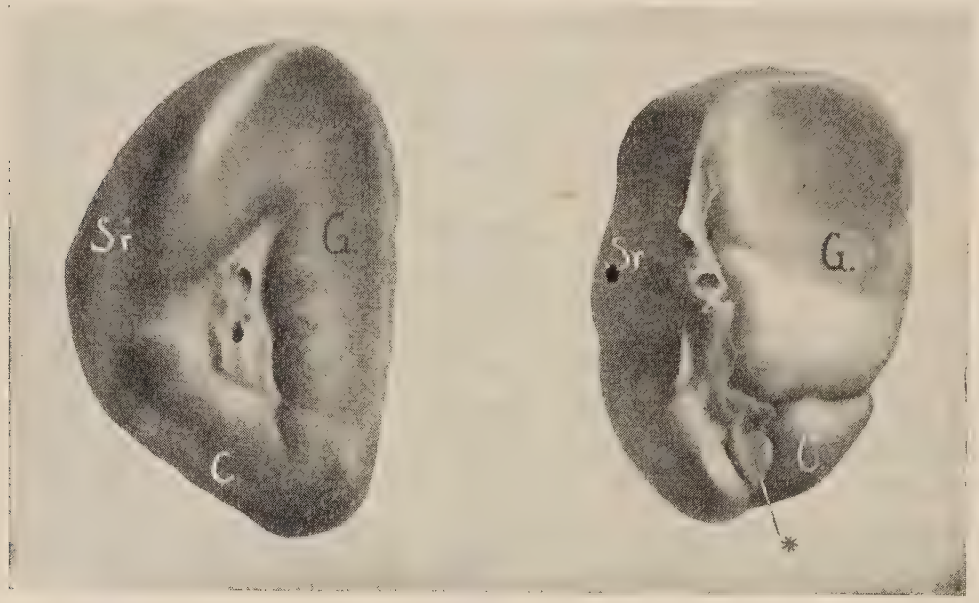

FIG. 173.—Drawings of the visceral surfaces of the spleens of two newborn children. C., colic surface; G., gastric surface; Sr., suprarenal surface; *accessory spleen. Natural size.

The modern methods of hematology have not been applied to the study of the spleen in infancy and our information regarding the finer structure of the organ at this time is most limited. Splenic, or Malpighian, corpuscles are developed in the latter half of fetal life. At birth they have much the same general structure as in later life. They form a larger proportion of the mass of the spleen and are placed closer together. The reticular fibers of the spleen do not differ greatly from those of the adult except in size. They continue to increase in thickness until puberty (Matsui[328]). Elastic fibers are present in the spleen as early as the sixth fetal month.

Accessory spleens are very common in young children. Jolly[325] found them in 25 per cent. of a series of 80 children less than seven years old and Sassuchin (quoted by Gundobin[7]) observed them in 23 cases in a series of 153 autopsies of children under 10 years. He found them much more common in newborn infants and sucklings than in older children.

THE THYMUS (Figs. 164, 174, 175, 176, 177, 178, 179)

Practically all observers who have examined large series of material find that the average weight of the thymus at birth is between 12 and 14 gm. In a series of 205 cases collected by the writer from personal observation and from the literature, the average weight was 13.2 gm. This series was limited to stillborn children and infants who died within 48 hours after birth; and no cases were included in which the body-weight was less than 2,700 gm. or the body-length less than 48 cm.

While the average weight of the thymus is about the same in all extensive series of cases the individual variations are very great. In the writer's series, the minimum weight was less than 2 gm. and the maximum weight was 28 gm. A frequency curve, based on this series, is shown in Fig. 174. As will be seen, the curve as a whole is a remarkably smooth one and it would be extremely difficult to draw a sharp line between the normal and abnormal cases on the basis of weight alone.

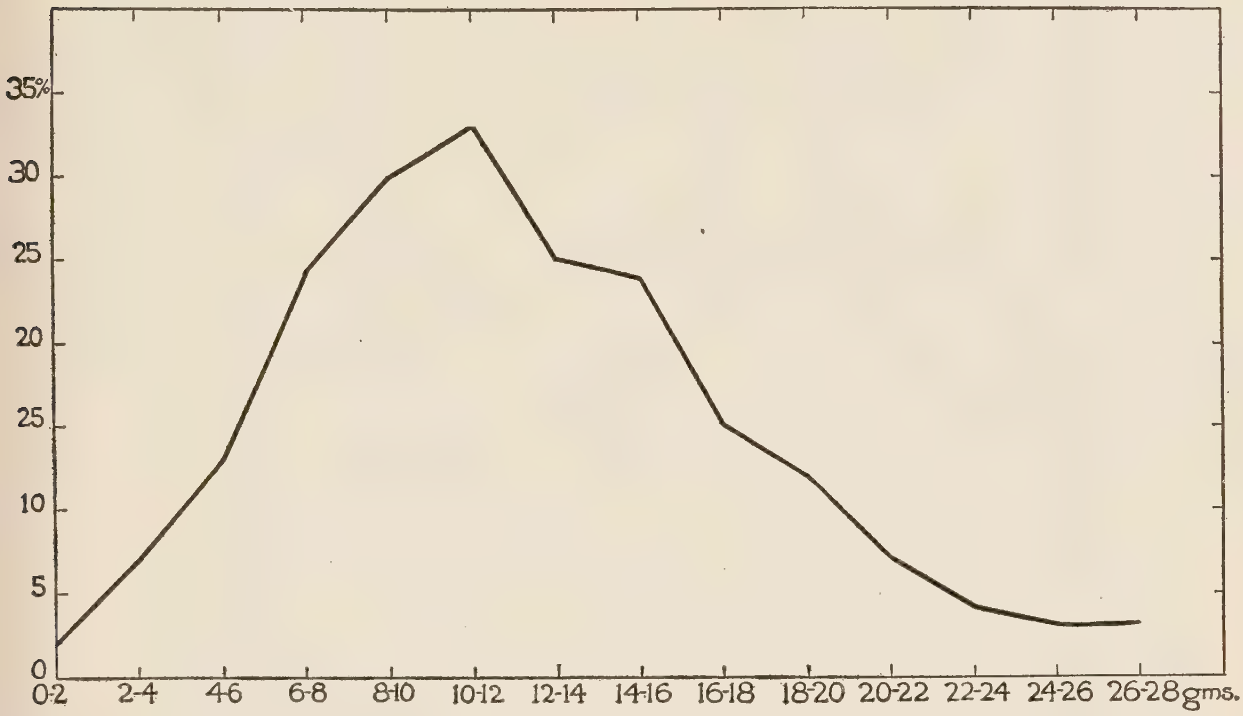

FIG. 174.—A percentage frequency graph showing the variation in weight of the thymus in full-term newborn children. Based on observations on 205 infants 48 cm. or more in length, or 2750 grams or more in weight which were still-born or died within 48 hours after birth.

The subject of the post-natal growth and involution of the thymus, which was in a state of great confusion for years, has been cleared up by the studies of Hammar.[322] He found that the weight of the gland increases steadily from birth to puberty; and then, as a rule, decreases slowly until the later years of life. The birth weight is doubled in the second lustrum and practically tripled in the third. Hammar's results are in conflict with the older view that the involution of the body began in infancy or early childhood, but their accuracy cannot be gainsaid. They are based upon abundant material which was selected with the greatest care both as to the previous history and the general bodily condition of the cases. The findings of von Sury,[332] and of Ronconi,[331] as well as the older work of Friedleben,[321] on selected cases, are confirmatory of Hammar's views. The lower weights which are quoted in most of the earlier literature are probably mainly from cases which had undergone accidental or hunger involution. The experimental studies of Jonson[326] show that this process takes place very rapidly and that a large part of the thymus weight may be lost before the body-weight is seriously affected. Hammar's results are shown in numerical form in

Table 27. Figure 175 is a graph showing the weight changes in the thymus during the first three decades. The curve in solid line is based upon Hammar's cases and the curve in broken line on Ronconi's Italian material. These two curves agree essentially although Ronconi's weights are consistently lower than those of Hammar—a difference which may be racial.

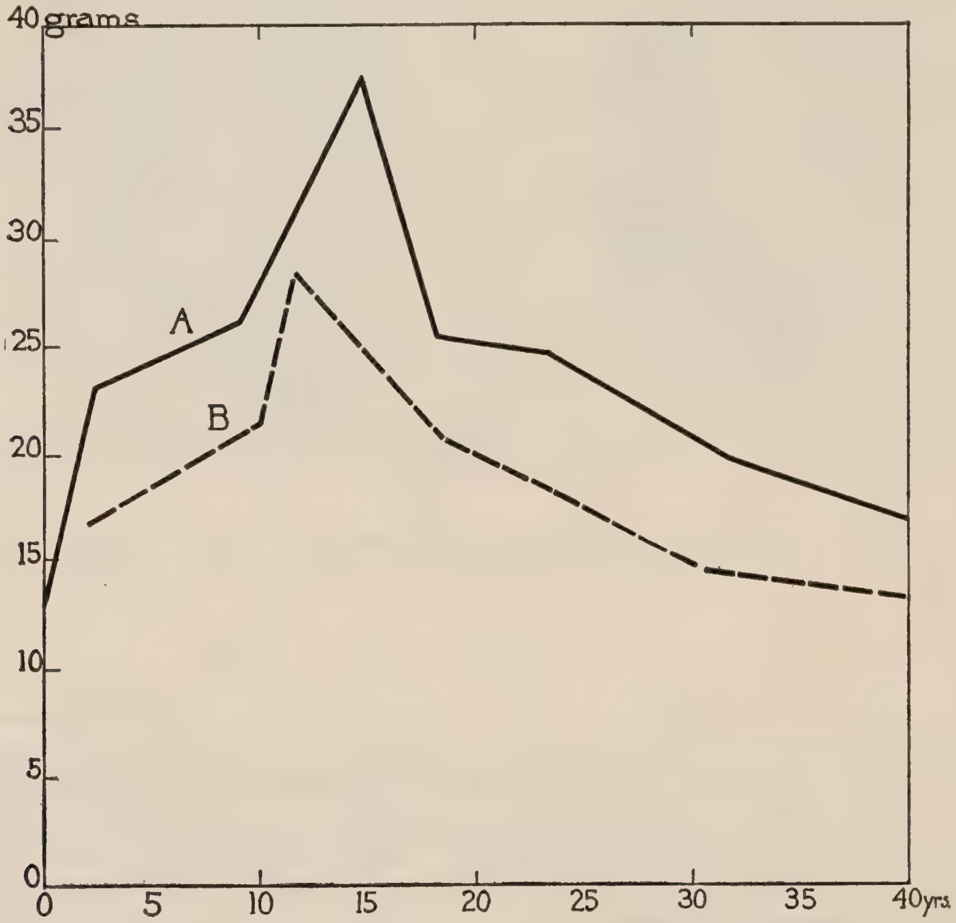

Fig. 175.—A graph illustrating the weight changes in the thymus during childhood and early maturity. Curve 'A' based upon the data of Hammar; curve 'B' based upon the data of Ronconi.

According to Hammar, the thymus forms 0.42 per cent. of the body-weight at birth. The relative weight drops to 0.12 per cent. in later childhood, 0.09 per cent. in adolescence and 0.05 to 0.03 per cent. in maturity.

The dimensions of the thymus are always quite variable. The series of observations by von Sury, which is quoted in Table 28, is among the most extensive on the subject and is based on selected cases. As will be seen from this table, the thymus becomes both relatively and absolutely longer in childhood, while breadth and thickness undergo but little absolute increase and are relatively reduced.

The form of the thymus is very inconstant, and any simple description of it will apply only to certain selected specimens. It is commonly described as consisting of two lateral lobes. Coplin[316] has recently proposed a classification of the forms of the thymus which is more satisfactory. He recognizes four main types as follows: (*a*) the unilobar type, of which he found but one specimen in a series of over

Table 27.—The Post-natal Weight-changes of the Thymus (After Hammar[322])

Age, years	Average age, years	Number of cases	Weight in grams			Per cent. of body-weight	Weight of paren-chyma	Per cent. of parenchyma as compared to total weight of gland	Weight of cortex, grams	Weight of medulla, grams
			Average	Minimum	Maximum					
Newborn	. . . . .	23	13.26	7.6	25.88	0.42	12.33	93.0	9.69	2.63
1 to 5	2.35	23	22.98	8.5	49.0	0.22	19.26	83.8	13.63	5.63
6 to 10	9.0	5	26.1	20.0	30.0	0.12	22.08	84.6	12.71	9.37
11 to 15	14.75	4	37.52	20.0	52.0	0.09	25.18	67.1	11.63	12.08
16 to 20	18.2	10	25.58	15.2	47.0	0.05	12.71	49.7	2.12	10.46
21 to 25	23.3	15	24.73	7.3	45.0	0.04	4.95	20.0	0.74	4.20
26 to 35	31.8	15	19.87	4.29	30.0	0.03	3.87	19.5	0.89	2.98
36 to 45	42.1	12	16.27	8.2	28.0	0.03	2.89	17.8	1.55	1.33
46 to 55	52.0	7	12.85	2.5	21.0	0.02	1.48	11.5		
56 to 65	62.0	6	16.08	5.6	30.0	0.03	0.73	4.5		
66 to 75	69.25	4	6.0	3.0	8.0	0.03	0.03	0.5		

500. (*b*) The bilobar type which is more common than the unilobar but is not the most frequent one (this is the type which is usually described as the "normal" one). (*c*) The trilobar type in which the gland is composed of two inferior and lateral masses and a median and superior one. Coplin finds this form the most common. (*d*) The conglomerate type in which no definite lobation is apparent. Some examples of the variable form of the body in the newborn are shown in Fig. 176. Noback[329] finds the bilobar type the most common (39462 cases examined).

TABLE 28.—THE AVERAGE WEIGHT AND DIMENSIONS OF THE THYMUS IN CHILDHOOD (AFTER V. SURY[332])

Age	Number of cases	Average weight, grams	Average dimensions, centimeters		
			Length	Breadth	Thickness
Birth	21	14.1	6.05	5.5	1.1
1st mo	10	15.9	5.8	5.2	1.4
2nd to 9th mo	27	24.3	7.4	5.6	1.5
9th mo. to 2 yrs	12	23.2	7.5	5.7	1.4
2 to 14 yrs	12	25.8	9.7	6.1	1.3

The relations of the thymus vary with its size. The description which follows is of the average gland. The relations of the thoracic and cervical portions of the body may be considered separately.

The thoracic portion of the thymus, in the child immediately after birth, is covered by the upper half of the sternum and generally by the first three costal cartilages. Its vertical extent corresponds to the firxt four thoracic vertebræ. The anterior surface of the gland is in contact medially with the endothoracic fascia covering the hinder surface of the sternum and with the internal mammary vessels. Laterally it lies behind the medial borders of the pleural sacs and in contact with the margins of the lungs. The posterior surface rests upon the great vessels of the superior mediastinum, the upper part of the thoracic portion of the trachea, and the upper part of the anterior surface of the heart. The relation of the posterior surface of the thymus to the left innominate vein is a very intimate one, and sometimes the vessel is partially imbedded in the thymus substance. As Hammar has pointed out, the thickest part of the gland lies immediately above the base of the heart and not at the superior thoracic aperture where the gland is supposed to exert pressure in cases of thymic enlargement.

The cervical portion of the gland is usually a tongue-like process which may lie in the mid-line or to one side. It may extend upward to the lower margin of the thyroid. It rests on the anterior surface of the trachea or the carotid sheath, and is covered by the anterior layer of the deep cervical fascia and the infrahyoid muscles. The cervical extension is sometimes entirely lacking or it may be represented by a fibrous band connecting the main mass of the thymus and the thyroid.

The changes in the form and relations of the thymus in the neonatal period have been recently worked out in detail by Noback. He finds that the change from the broad type of gland characteristic of the fetus to the elongated type found in the young infant bears a direct relation to the establishment of respiration, and is dependent on the expansion of the lungs. The organ is compressed from side to side by the medial surfaces of the expanding lungs, and is also compressed anteroposteriorly by the anterior borders of these structures as they become thickened with the establishment of respiration. After respiration is established the thymus usually extends more inferiorly passing over the right ventricle.

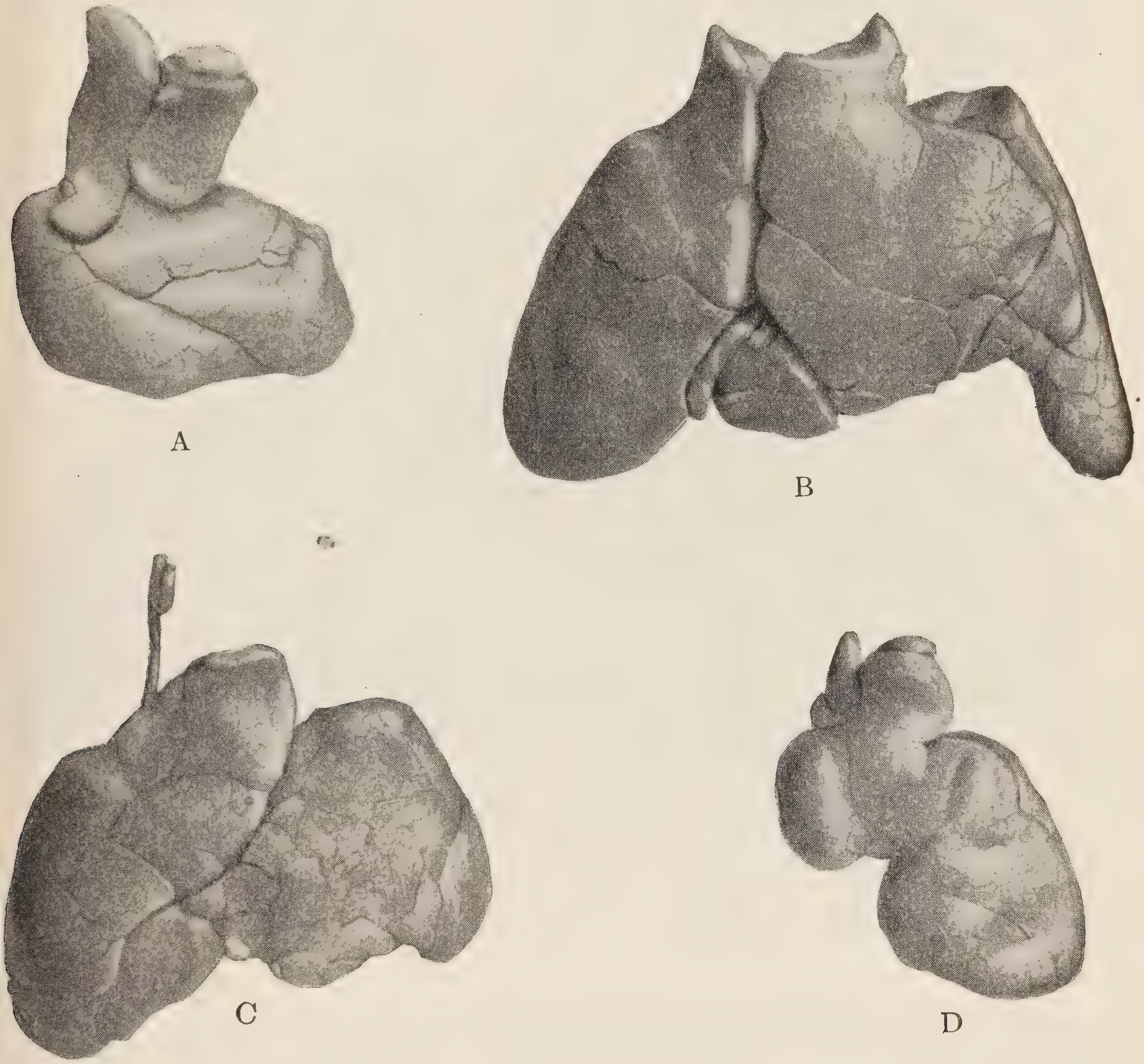

Fig. 176.—Anterior views of the thymi of four full-term newborn children. The specimens are from material hardened in situ. Natural size.

The thymus gradually becomes longer and narrower in infancy and childhood, but its lateral margins generally still remain in contact or under the cover of the medial edges of the lungs. As the gland elongates it extends downward over the greater part of the anterior surface, and the cervical portion becomes less noticeable.

The histological picture of the thymus changes greatly with age. In the newborn the parenchyma is very abundant, forming, according to Hammar, 93 per cent. of the gland. The lobules are large and angular, and are separated by very narrow trabeculæ of delicate connective tissue. The cortex forms by far the larger proportion of the parenchyma and shows very little division into secondary nodules. Thymic or Hassel's corpuscles are numerous but are not as abundant as in later life.

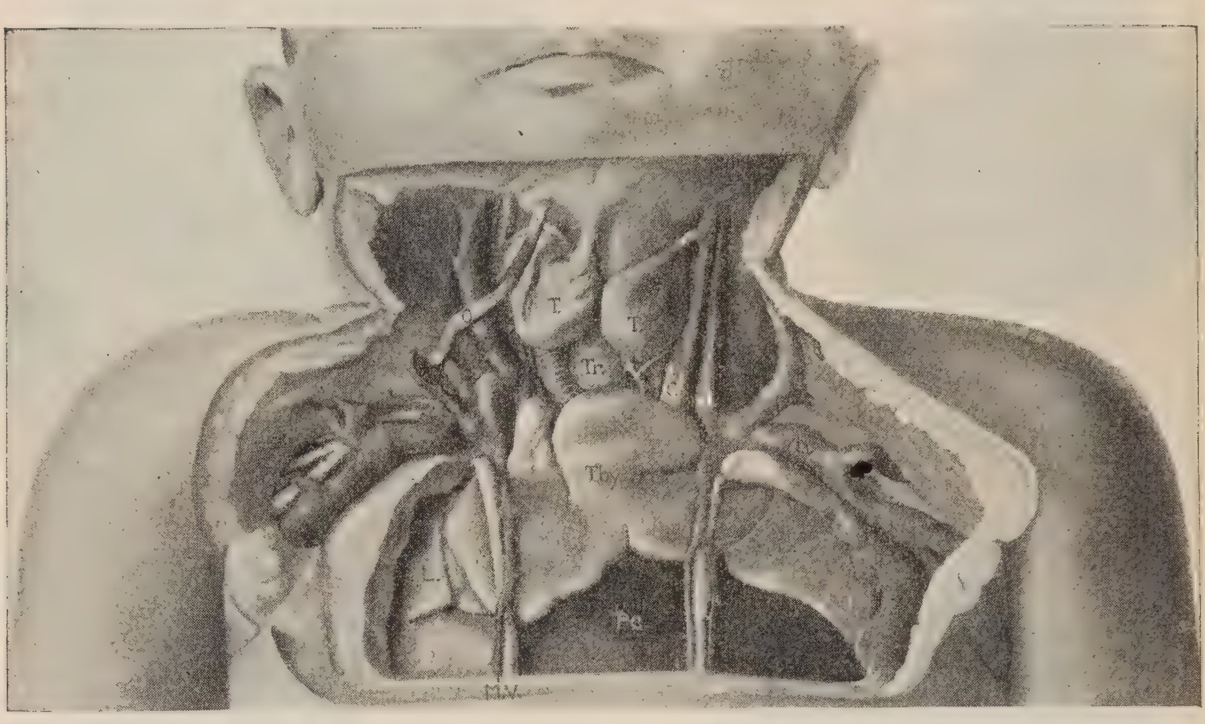

Fig. 177.—A dissection of the neck and superior mediastinum of a postmature, newborn, female child weighing over 4000 grams. A.v., axillary vein; C., left common carotid artery; J., internal jugular vein; L., lung; M.V., internal mammary vessels; O., omohyoid muscle; Pc., pericardium; T., thyroid gland; Thy., thymus gland; Tr., trachea. Three-fourths natural size.

During childhood all parts of the thymus grow rapidly, but the relative increase of the interlobular connective is greater than that of the parenchyma. The medullary portion of the lobules also increases more than the cortical part, and the latter is partially subdivided by the ingrowth of narrow secondary connective tissue septa.

At and after puberty the connective tissue framework of the gland becomes still more noticeable, the interlobular septa are much thicker, and the secondary septa which mark off the nodules of the cortex are widened. The medulla forms the major part of the parenchyma and the cortex is broken up into a series of rounded nodules. The thymic corpuscles are considerably increased.

In early maturity the interstitial connective tissue forms as much or more of the gland than the parenchyma and the cortical nodules of the lobules are reduced to rounded projections from the medulla.

Fat cells are sometimes found in the thymus at birth but they grow very little until early maturity when there is a marked increase in the amount of adipose tissue in the septa.

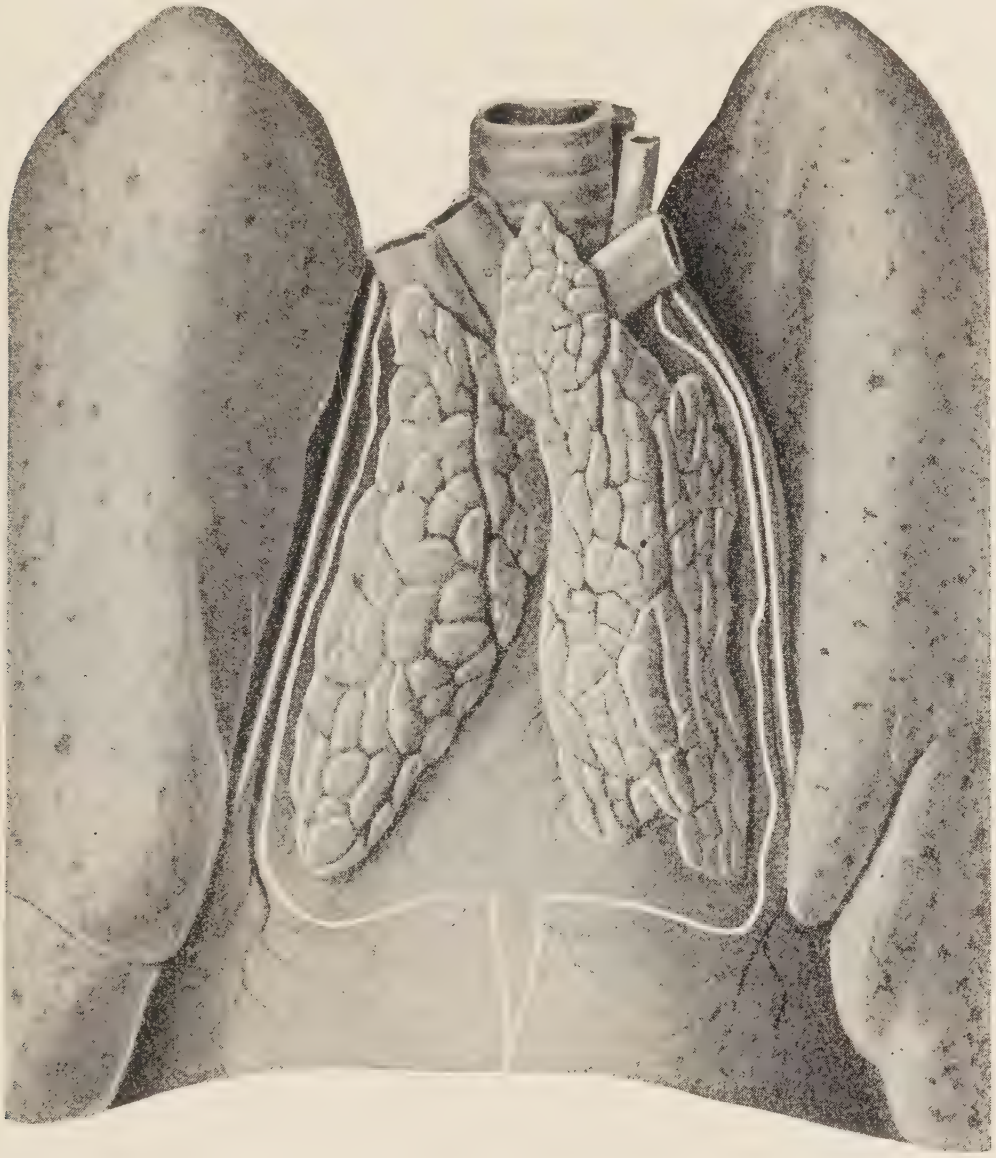

FIG. 178.—Thymus of a girl 14 years old. (After Sobotta in Bardeleben's Handb. d. Anat. d. Menschen. Bd. VI.)

Accessory masses of thymic tissue are not unusual in childhood. They are sometimes found in the immediate region of the main body of the gland, but are more common in the cervical region in the neighborhood of the thyroid or even in the carotid triangles.

THE CENTRAL NERVOUS SYSTEM AND THE ORGANS OF SPECIAL SENSE

THE BRAIN (Figs. 133, 135, 180, 181, 182,)

The weight of the brain in the full-term Caucasian newborn varies from 300 to 400 gm. and averages about 350 gm. The variation in the weight of the brain at birth, while seemingly great, is relatively less than in any other organ of the body with the possible exception of the eyeball. It is dependent to some degree on bodily development and to a lesser one on sex, the brains of newborn males being slightly heavier absolutely than those of females. The total weight of the brain increases from three and one-half to four times between birth and maturity. The growth of the brain may be divided into three periods. From birth to the end of the first year the growth is very rapid and the brain increases approximately two and one-half times in weight. From the end of the first to the middle of the fifth year growth continues at a reduced although still a rapid rate, and by the end of this period the brain weighs about three times as much as at birth. After this time brain growth is very slow indeed and the adult weight is acquired by the end of the fifteenth year. Putting this statement in another form the brain accomplishes about one-third of its total absolute post-natal growth in the first year, one-third between one and two and one-quarter years, and the final third between two and one-quarter years and fifteen years. There is probably little if any increase in brain weight after 15 years, and in some cases the average adult brain weight is acquired by the seventh year. A period of increased brain growth at puberty has been described, but the writer's examination of most of the published data on brain weights in children fails to confirm this observation. Throughout childhood the brains of boys average absolutely heavier than those of girls. There is, however, no evidence of much difference in the relative brain weights in the two sexes.

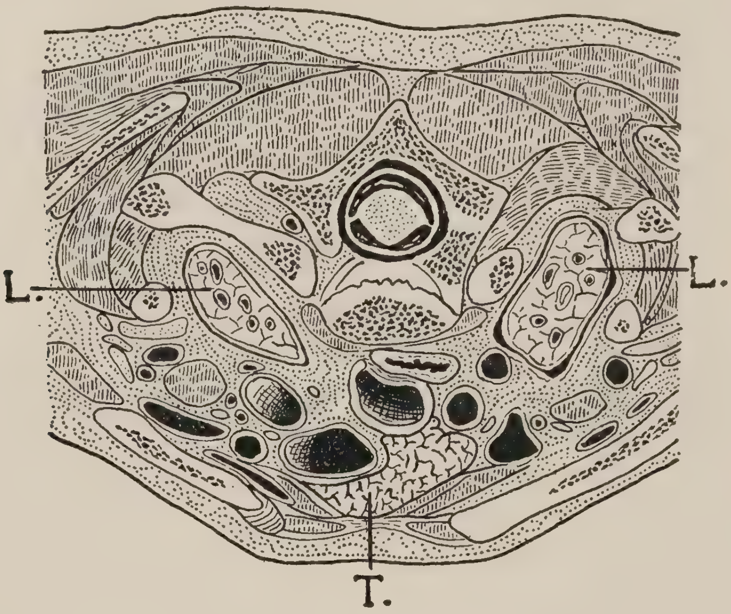

FIG. 179.—Transverse section of the superior aperture of the thorax of a girl three years old, showing the position of the thymus. L., lung; T., thymus. (After Dwight.[4])

The relative weight of the brain as compared to that of the body is very high at birth, being from 1:8 to 1:10. In the adult, according to Ziehen, the relation is 1:42 in males and 1:40 in females.

According to the data of Pfeister,[351] the weight of the cerebrum at birth is from 305 to 345 gm. At this time it forms about 93 per cent. of the entire brain weight. The total post-natal weight increase of the cerebrum amounts to 840 gm. or even more. Nearly one-third of this increase takes place in the first ninemonths, and nearly two-thirds in the first two years. The frontal lobes grow more than do the other parts of the cerebrum. The relation of the grey matter of the cortex to the white matter of the medulla has been determined by Anton[335] and Jaeger[345] by means of the polar planimeter. The former found that the relation of the volume of the cortex to the volume of the medulla in the child was as 1:2 in the frontal lobe and as 1:3 in the occipital lobe; in the adult the corresponding relations were 4:5 in the frontal lobe and 1:2 in the occipital lobe. Jaeger's results in general support those of Anton. Aresu,[336] on the other hand, using a more elaborate method, found that the cortical grey matter formed 58 per cent. of the weight of the entire cerebrum in an infant one year and four months old; 67 and 43 per cent. respectively in two children of two years; 77 per cent. in a child of four years and 67 and 64 per cent. respectively in two young adults. There have been no extensive studies on the growth of the basal ganglia of the cerebrum, but Franceschi (quoted by Donaldson[341]) found that these masses weighed 24 to 25 gm. in two children under five years of age as compared with about 41 gm. in the adult.

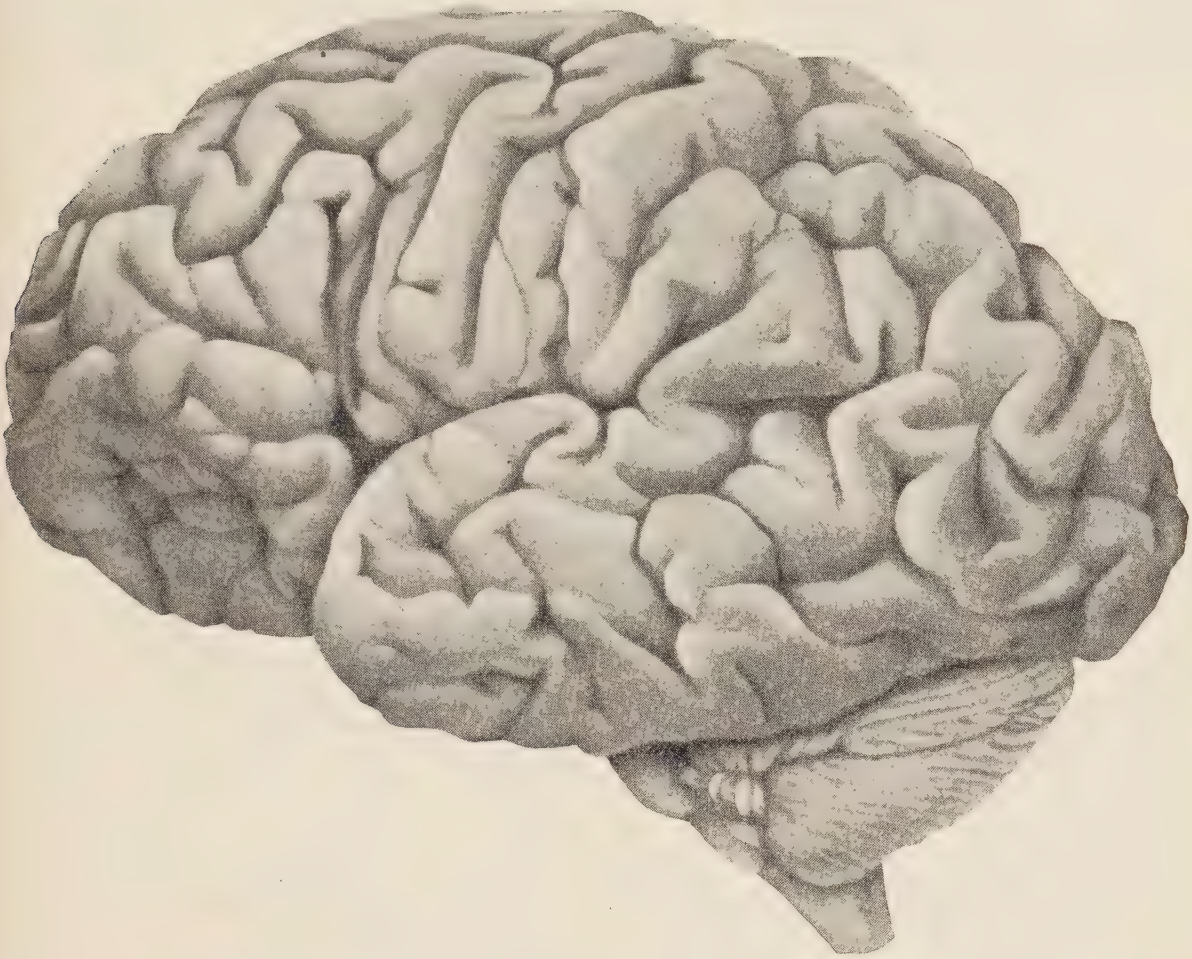

FIG. 180.—Left lateral view of the brain of a male, newborn child 53 cm. long. Natural size. (After Retzius.[353])

The cerebellum weighs from 18 to 20 gm. at birth, thus forming about 5 or 6 per cent. of the entire brain weight. During the entire period of post-natal growth it increases about seven-fold or nearly twice as much as the brain as a whole. One-third of this growth is accomplished in the first six months, and two-thirds in the first year and three-quarters after birth (Pfeister[351]). During this period the relative weight as compared with that of the whole brain rises from 5 or 6 to 10 or 11 per cent., which is the ratio in the adult.

The brain stem weighs about 5.0 gm. at birth and 25 to 28 gm. in maturity. Its growth in early infancy is a little slower than that of the brain as a whole but the total relative increase after birth is somewhat greater.

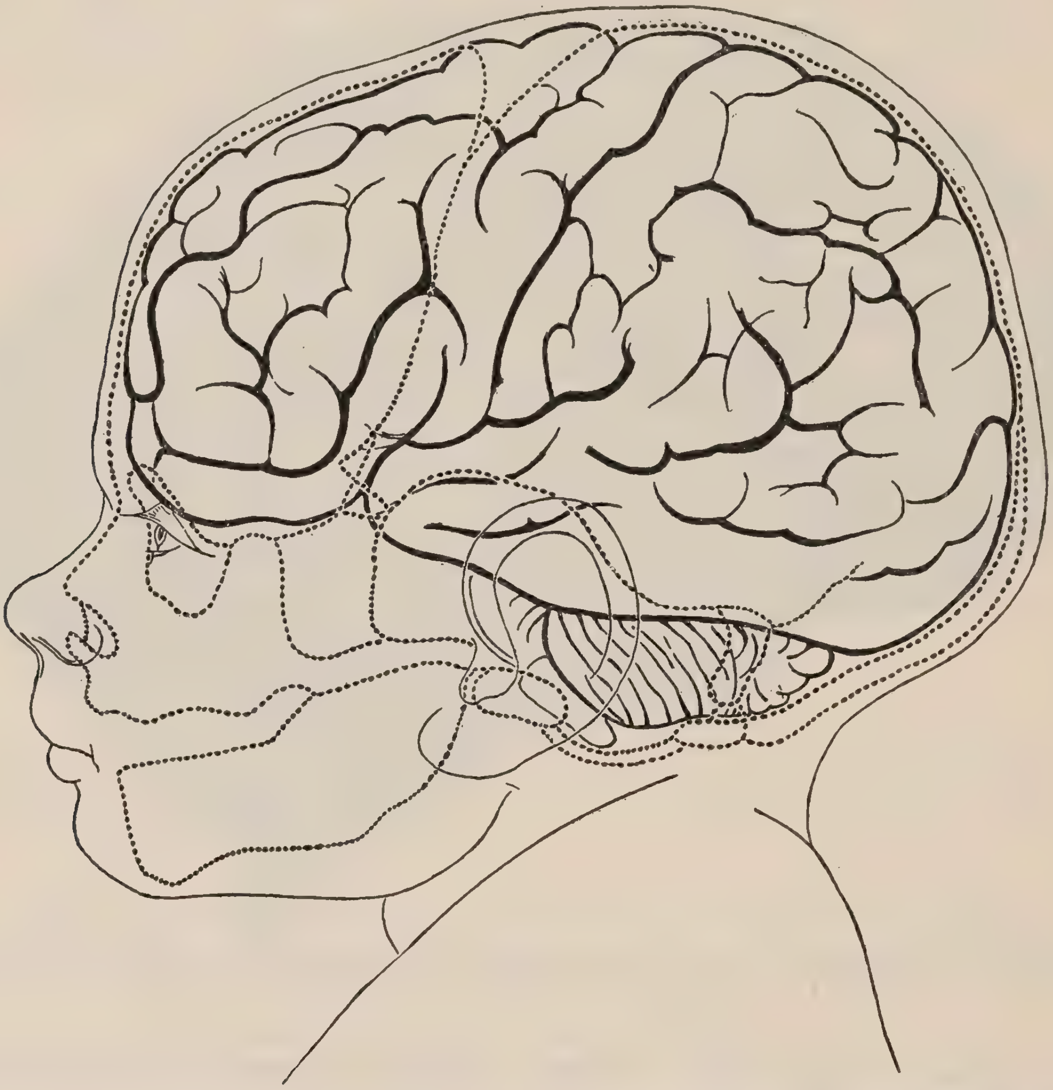

Fig. 181.—Lateral view of the head of a newborn child showing the topography of the skull and brain. Surface outlines in light line, skeletal structures in broken line, brain in heavy solid line. (After Merkel, Handb. top. Anat.)

The state of development of the sulci of the cerebrum at birth is illustrated by Fig. 180, a left lateral view of the brain of a full-term fetus. As will be seen from this figure, the general arrangement and condition of the sulci does not differ greatly from that of the adult. New lateral branches of established sulci may appear and the fusion of isolated segments to form continuous furrows may take place after birth, but these changes are small and are accomplished in the first month or so of post-natal life. The insula, or island of Reil, is not as completely covered at birth as in later life.

Space will not permit the discussion of the finer structure of the brain in this summary. The reader is recommended to the work of

Brodmann,[338] Flechsig,[342] and Hammerberg[344] for information on this subject.

The topographic relations of the more important sulci to the skull are somewhat different in the child and in the adult. The post-natal changes in these relations are brought about not as much by the shifting of the sulci, although this process has been described, as by developmental changes in the calvarium. In the infant the lateral fissure (of Sylvius) is more oblique than in later life, and lies from 1.1 to 1.5 cm. above the squamosal suture. It extends backward and upward nearly to the parietal eminence. The lateral fissure and the squamosal suture approach one another during childhood, but the time at which the adult relationship is acquired is probably very variable; Symington[14] sets it at the eighth or ninth year. The central sulcus (fissure of Rolando) lies entirely under the cover of the parietal bone in the infant as in the adult, but it is placed a little farther forward in the former. At birth and for a short time thereafter, at least, the sulcus is more oblique than in the adult. Fouillehouze[343] found the upper end to be from 30 to 35 mm. posterior to the bregma in the first few months of life, while the lower end may touch the coronal suture. After the third

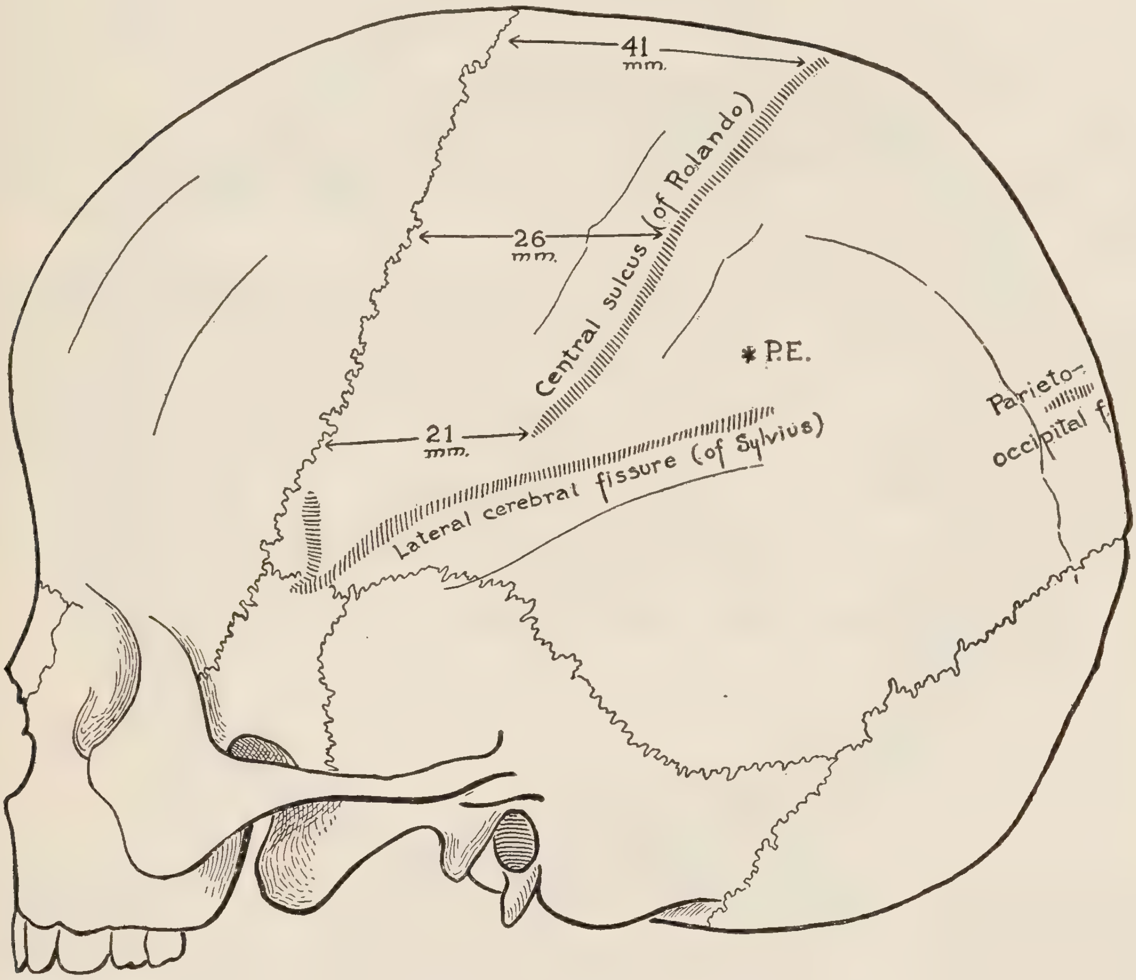
41 mm.
Central sulcus (of Rolando)
26 mm.
21 mm.
P.E.
Lateral cerebral fissure (of Sylvius)
Parieto-occipital f.

FIG. 182.—Lateral view of the skull of a child four years of age showing the position of the main cerebral fissures. P.E., parietal eminence. (After Davis from Fouillehouze.[343])

year the relations are the same as in the adult. The parietooccipital fissure in infants lies from 5 to 15 or even 20 mm. in front of the lamboid suture. This is relatively a little anterior to its position in the adult. Figures 181 and 182 show the position of the main fissures in early childhood.

THE MENINGES AND CRANIAL SINUSES (Figs. 90–186)

The form and relations of the meninges in the child are very similar to those of the adult. The dura is more closely applied to the cranial bones in early life and its outer layer contains numerous osteoblasts. It is continued across the sutures and forms the inner layer of the fontanicular membranes. Judging from the data of Pfeister,[350] the dura grows at approximately the same rate as the brain and not at the general body rate; for its weight in the first month is about 22 gm. and this is only tripled by seven years.

The relation between brain volume and cranial capacity differs in the adult and child. In the newborn the brain occupies 97.5 per cent. of the cranial cavity and this relation is hardly changed in the first six years. After six years the space between the brain and the cranial wall steadily increases and in the adult the brain occupies, on the average, only 92.5 per cent. of the cranial cavity. In other words, the brain is much more closely applied to the wall of the skull during its period of rapid growth than in later life.

The topography of the cranial sinuses in the child has not been studied in detail.

THE SPINAL CORD (Fig. 151)

The weight, in the newborn, of the spinal cord without its dural covering or the spinal nerve roots is between 3 and 3.5 gm., being about one-eighth that of the adult. According to Pfeister the weight of the cord is doubled in the first five months, trebled in the first year, and quadrupled by the beginning of the third year. The spinal cord forms about 1 per cent. of the body weight at birth and about 0.25 per cent. in the adult. The weight of the spinal cord is to the weight of the brain at birth as 1:110, and in the adult (Pfeister) as 1:50.

At birth the spinal cord is from 15 to 17 cm. in length; a little more than one-third as long as in the adult. It doubles its length in the first 10 years of life. The length of the various segments of the cord are so variable at all times of life that no general statement can be hazarded as to their rates of growth, although it is said that the thoracic segment lengthens more, proportionately, than the others. The cord at birth commonly terminates at the lower border of the body of the second or the upper margin of the third lumbar vertebra, about one vertebra below the usual point of termination in the adult.

THE EYE (Fig. 183)

The post-natal growth of the eyeball corresponds very closely to that of the brain. At birth its average weight is from 2.5 to 3.0 gm. This is increased approximately two times in the first seven or eight years of life. In all, the weight of the eye-ball increases about three times between birth and maturity. During the same period the brain increases from three and one-half to four times and the body over 20 times.

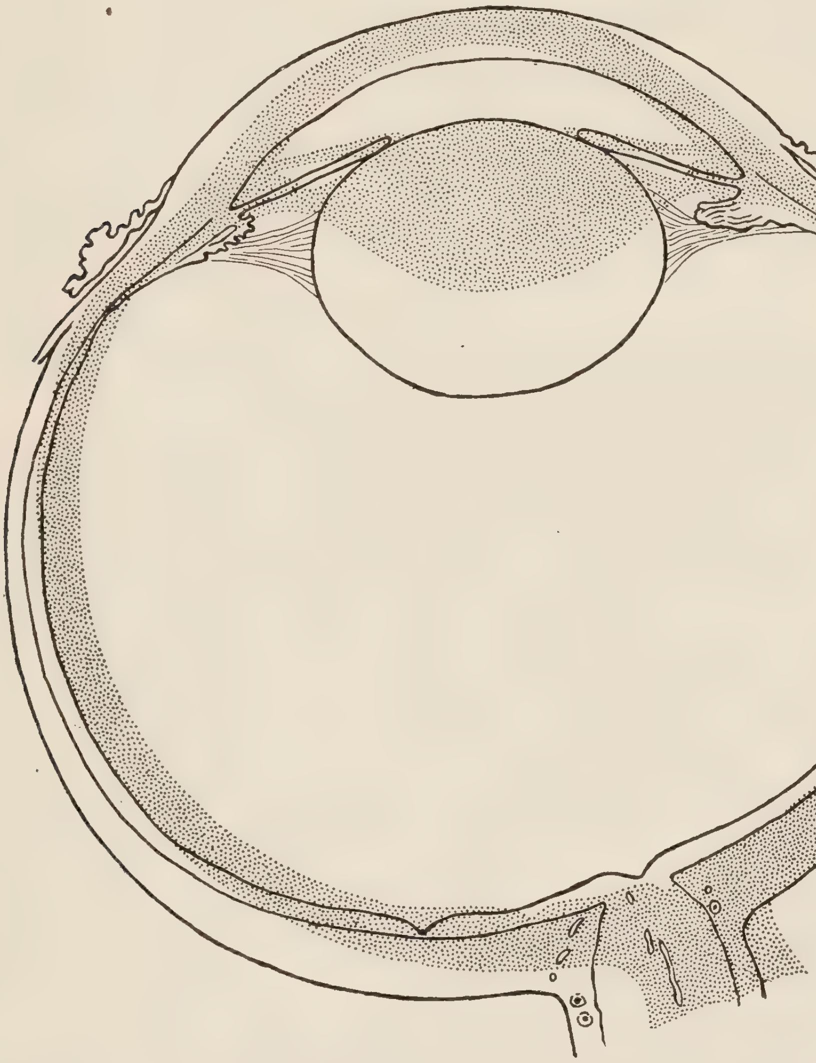

FIG. 183.—Semidiagrammatic representation of the eye of the newborn in median section superimposed upon a similar section of the eye of the adult. The structures are drawn at equal size. The newborn eye is represented in solid line, the adult in stipple. The newborn eye is magnified five times. (After Merkel and Orr.[360])

The volume of the eye increases slightly more but at the same relative rate as the weight.

Considerable difference in the averages of the several diameters of the eye-ball at birth is found by different observers. This is no doubt partly due to natural variation and partly to the deformation of the eye-ball after removal from the body. Weiss[365] in a series of 20 newborn children found the sagittal diameter to be 16.4 mm., the horizontal 16.0 mm., and the vertical 15.4 mm. In the adult the similar measurements are 23.85, 24.43, and 23.7 mm. Thus the sagittal diameter, according to these figures, is relatively a little greater in the newborn than in the adult. The actual increase in the lengths of the several diameters between birth and maturity is something less than one and one-half times for the sagittal diameter and a little more than one and one-half times for the vertical diameters.

The growth of the eyeball as a whole takes place in different regions in different periods of post-natal life. The divergence of the eyeball from a perfect sphere is more marked in infancy than in later life. This is due particularly to the great size of the posterio-temporal segment. In early childhood the anterior segment grows the most rapidly; in later childhood growth appears to be more localized in the nasal segment. After puberty the posterior segment completes its growth. This does not apply to the area of the posterior segment about the fovea centralis and the papilla of the optic nerve, for the distance between these two structures is as great in the newborn as it is in the adult.

The cornea in the newborn is relatively larger than in later life, being almost four-fifths the actual size of that of the adult. Its curvature is less pronounced than that of the adult.

The shape of the lens in the newborn and young infant is not markedly different from that found in later life. The familiar statement that the lens is much thicker relatively in the newborn than the adult rests upon observations made on fixed material and upon specimens which have been freed of their attachments. Both von Pflugk[361] and von Hipple,[357] who studied fresh lenses in section, found the thickness to be from 3.5 to 4 mm. and the equatorial diameter from 6 to 7 mm. Most earlier observers found the thickness of the lens to be more than two-thirds of its equatorial diameter. The equatorial diameter of the lens increases during the entire period of life up to an advanced age. In the period from birth to the end of the third decade it increases between a third and a fourth. The growth in thickness is not so regular for there seems to be a period of actual decrease in thickness in early childhood. This is probably due to the effect of the tension of the supporting structures on the plastic lens substance. After early childhood the thickness of the lens increases throughout the remainder of life.

During the growth of the eyeball its extrinsic muscles are slightly shifted from their original position. The reader is referred to the work of Weiss[365] on this subject for details.

The optic nerve increases more than one-half in diameter during the first year and by the end of that time is substantially the same size as in the adult. Most of this early increase is due to the myelination of the optic nerve fibers, a process which takes place mainly during the first three weeks of post-natal life. As in the adult, the optic nerve is slightly sinuous in its course through the orbit.

The lachrymal gland weighs at birth approximately one-third of its adult weight. At this time the parenchyma consists of narrow thick-walled tubes separated by a large amount of cellular connective tissue. The fat which is abundant in the adult gland is lacking in that of the infant. Although incompletely developed at the time of birth the gland has a limited power of secretion.

THE EAR (INCLUDING THE TEMPORAL BONE)

The ear can be treated only in the briefest manner in the present outline. Those desiring more detailed accounts are referred particularly to the papers of Alexander,[367] Brown,[369] Freligh,[371] and Symington.[376] The atlas of Müller gives excellent figures of the topography of the temporal region in childhood.

The Temporal Bone (Figs. 182, 184, 185).—At birth the temporal bone as a whole is approximately one-fourth the size of the adult. It consists of three divisions: The pars petrosa, the pars squamosa, and the pars tympanica, which are generally still separated by definite sutures. The styloid process is still entirely cartilaginous except for a small osseous granule near its upper end.

The petrous portion is relatively larger than in later life. It is directed more anteriorly and inferiorly and less medially than in the adult. The mastoid process is absent and the external surface of the bone presents a smooth flat area which is not elevated above the general surface of the skull in this region. The stylomastoid foramen, which is relatively larger than in later life, is found at the anterior edge of this area.

The pars squamosa is thin and smooth. The mandibular, or glenoid fossa, is of considerable size although very shallow. A true articular tubercle is lacking but the postglenoid process is well marked.

The pars tympanica or tympanic annulus has the form of a thin bony ring which is incomplete above. The upper extremities of the ring are usually fused with the inferior margin of the pars squamosa at the time of birth.

In the newborn the petrous and the squamosal portions of the temporal bone are almost always partially separated by a fissure, the petrosquamosal suture. This cleft arises behind the middle of the posterior limb of the tympanic ring, and extends upward and backward on the lateral surface of the bone to its superior margin. It then turns forward and runs in the roof of the tympanum until it reaches the anterior margin of the squamous portion of the bone. The petrosquamosal suture opens directly into the tympanic antrum in the newborn and in young children, and its presence accounts for the frequent spreading of middle ear infections to the meninges and for the formation of subperiosteal abscesses in early life.

The form of the temporal bone changes rapidly in childhood. The mastoid process generally appears as a small nipple-like projection during the latter part of the first year, but it does not extend below the general inferior margin for two or three years thereafter. The upper osseous center in the upper part of the styloid process fuses with the body of the bone soon after birth. A second lower center appears

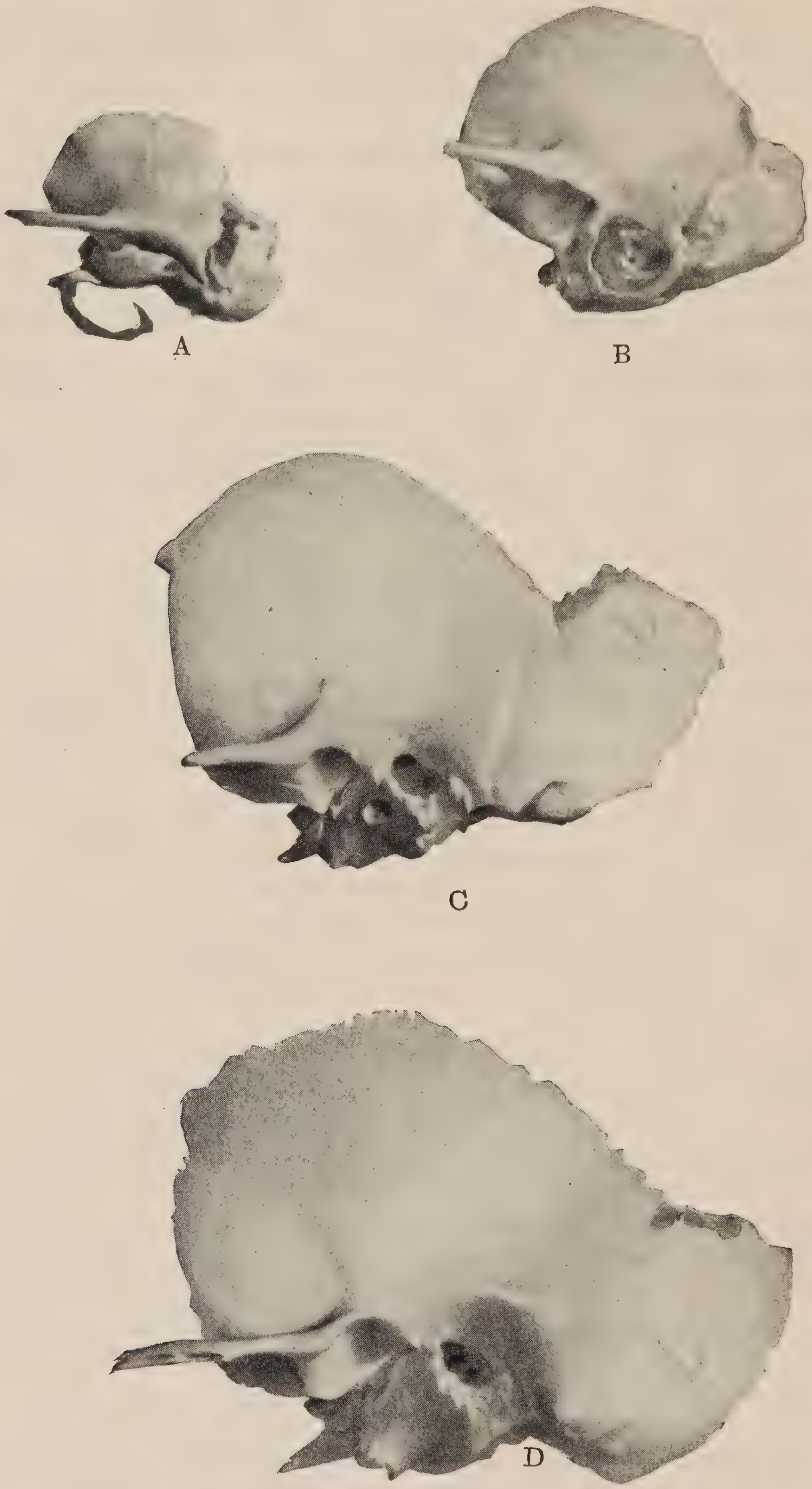

FIG. 184.—Four drawings of the temporal bone in early life. A, seven months fetus; B, full-term newborn; C, child three years old; D, child six years old. All natural size.

in the styloid cartilage about the eighth year, and joins the main bone about puberty.

The tympanic annulus is converted into a plate by the rapid growth of processes from its anterior and posterior sides. The lower part of the annulus does not grow as rapidly as do the sides and there is left a deep notch in the floor of the bony meatus. The processes from the sides of the annulus fuse inferiorly at about two years and the notch is thus converted into a foramen. This is generally obliterated in the next few years although in some cases it may persist in adult life. While the floor and sides of the bony meatus are formed mainly from the lateral growth of the tympanic ring, the roof is produced by the outgrowth of a bony shelf from the pars squamosa.

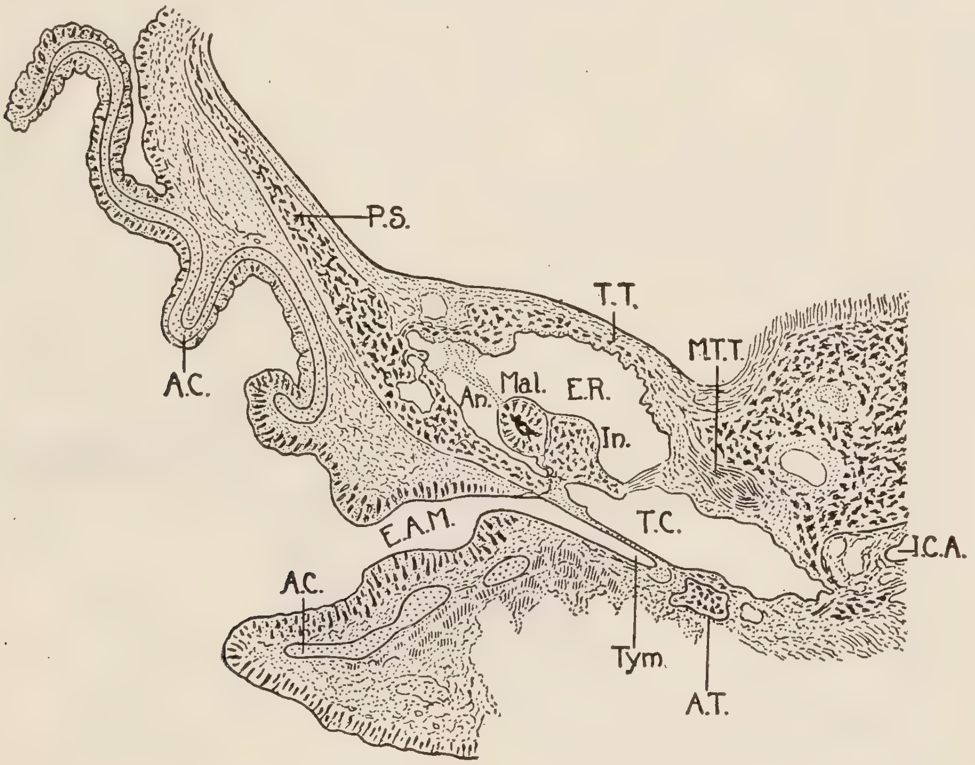

Fig. 185.—Vertical section of the ear of a newborn child. A.C., auricular cartilages; Ant., tympanic antrum; A.T., tympanic annulus; E.A.M., external auditory meatus; E.R., epitympanic recess; I.C.A., internal carotid artery; In., incus; Mal., malleus; M.T.T., tensor tympani muscle; P.S., squamous part of temporal bone; T.C., tympanic cavity; T.T., tegmen tympani; Tym., tympanic membrane. Four times natural size. (Slightly modified from Hammar.[374])

The closure of the petrosquamosal fissure is subject to the greatest variation in different individuals. Kisselbach[372] found it closed completely in about 4 per cent. of children in the first year, in from one-third to one-half of his cases between one and five years, and in 60 to 80 per cent. between 5 and 19 years. His statistics show no indication of a progressive closure of the fissure after the sixth year. In many cases it is obliterated except for minor holes and clefts.

The specimens illustrated in Fig. 184 show some of the more important gross changes in the form of the bone after birth.

The External Ear (Fig. 185).—The longitudinal dimensions of the external auditory meatus are subject to great individual variation, but in general they are about two-thirds those of the adult. The relative length of the tube is somewhat greater in early life than in maturity. In the infant the floor of the tube is formed externally of cartilage, and internally by a dense fibrous membrane which is replaced later by the bony outgrowth of the tympanic plate. The inner third of the roof is formed by the overhanging lateral surface of the pars squamosa while the outer two-thirds is cartilaginous.

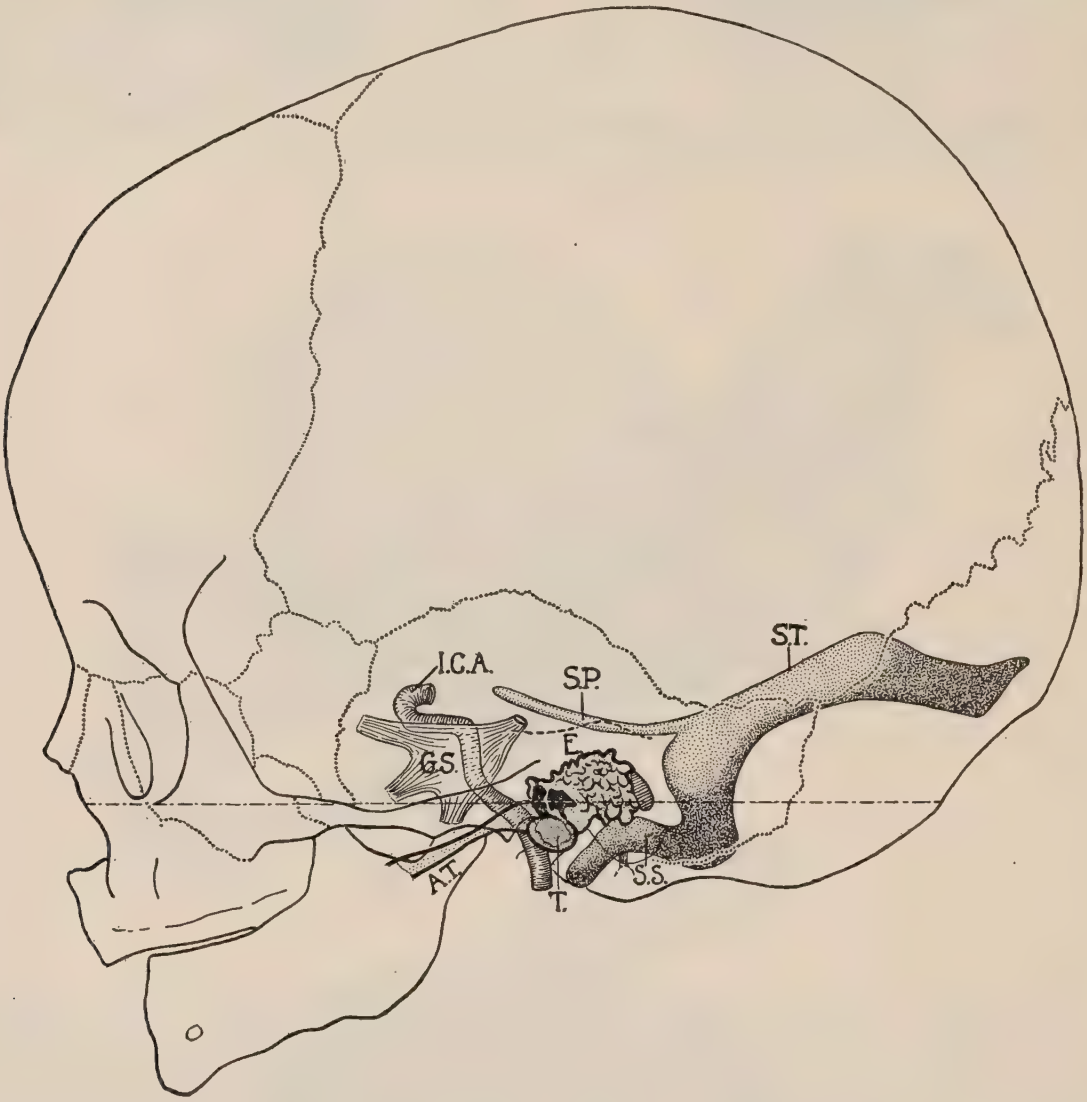

Fig. 186.—Left lateral view of the skull of a female child 12 months old, showing the topography of the ear. A.T., auditory tube; E., epitympanic recess, mastoid antrum, and mastoid air cells; G.S., semilunar ganglion; I.C.A., internal carotid artery; S.P., superior petrosal sinus; S.S., sigmoid sinus; S.T., transverse sinus; T., tympanic membrane. (After Müller.[375])

The lumen of the middle part of the tube is very narrow in infancy, but it widens out into a conical chamber near the tympanic membrane. At birth the lumen is filled by a mass of desquamated epithelial cells and vernix caseosa.

In infancy the course of the meatus is almost straight; it passes inward, downward, and slightly forward.

The Middle Ear (Figs. 185, 186, 187).—The cavity of the tympanum has practically reached its final size at birth. The average dimensions, as determined by Freligh from the measurement of 150 cases, are 9.5

mm. in its longest diameter by 7.5 mm. across. The promontory is well marked, as is also the prominence of the facial canal. The epitympanic recess (aditus ad antrum) and the tympanic (mastoid) antrum are quite as large if not absolutely larger in the infant than in the adult. In the late fetus the tympanic cavity is almost completely filled with a jelly-like tissue derived from the lining epithelium. This is generally replaced by fluid before birth and by air after respiration is fully established. Meconium and amniotic fluid have often been found in the tympanic cavities of newborn children.

The tympanic membrane has practically completed its growth by the time of birth. Its inclination is much the same in the infant and in the adult, the angle being generally between 50 and 60° in both. The external surface of the membrane is directed somewhat more anteriorly in childhood than in later life. The epithelia covering the inner and outer surfaces of the tympanic membrane are somewhat thicker in the child than in the adult, but the intervening connective tissue layer is about the same. The inner epithelial layer is ciliated at birth.

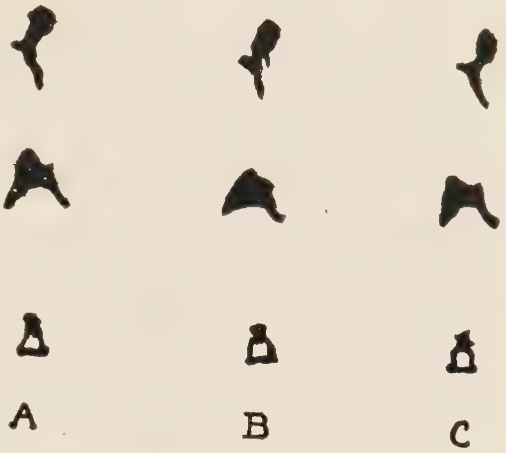

Fig. 187.—Drawings of the auditory ossicles: A, of a fetus of seven months; B, of a newborn child; C, of an adult. All natural size. (After Broman.[368])

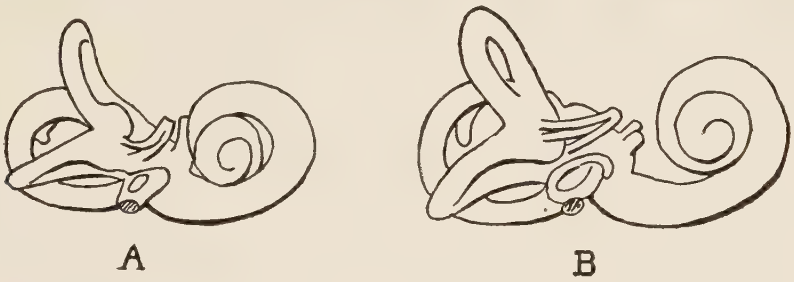

Fig. 188.—Casts of the labyrinth of the inner ear, three times natural size. A, newborn; B, adult. (After Alexander.[366])

The auditory ossicles reach their final size in the middle of fetal life. This is strikingly shown in Fig. 187.

The auditory, or Eustachian, tube is about 17 mm. long in the newborn or approximately half the length of the adult. According to the measurements of Symington, it grows rather slowly in the first year but rapidly thereafter, so that the adult length is approached by the end of the first period of childhood. The tympanic opening of the tube is quite as large in the newborn as in the adult, while the isthmus is absolutely as well as relatively wider. The pharyngeal opening, on the other hand, is relatively small. The bony part of the tube is relatively longer in infancy than in maturity. The course of the tube is almost horizontal in the infant, and the obliquity of the adult tube is acquired along with the increase in length of the nasopharynx in later childhood. The shifting of the pharyngeal ostium of the tube in childhood has already been described in connection with the nasopharynx. The "tonsil" of the tube is represented only by diffuse lymphoid tissue in the newborn. It acquires its final form in the third or fourth year.

The development of the mastoid cells is very irregular. Freligh[371] found them present in 30 per cent. of the large series of temporal bones of the newborn which he examined. In this series the largest cells were about 5 mm. in diameter. Most of these cells were located just posterior to the exit of the facial nerve, and none were found at the lower end of the mastoid portion of the pars petrosa. In childhood the core of the developing mastoid process is filled with fine cancellous bone, and as a rule this region is not invaded by the mastoid cells until nearly puberty. However there are cases in which the process contains cells of a considerable size at five or six years.

The Internal Ear (Fig. 188).—The structure of the internal ear in childhood needs no particular description. The bony labyrinth has attained almost its adult size and proportions at the time of birth. The careful series of measurements made by Alexander[366] show that most of the dimensions of the vestibule and semicircular canals increase about one-tenth during post-natal life while those of the cochlea, on the whole, increase rather less. Certain dimensions, such, for example, as those of the fenestra cochlea (fenestra rotunda), are practically the same in the newborn and the adult. Figures 188*a* and 188*b* are of casts of the osseous labyrinths of the newborn and adult drawn at natural size.

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